TITLE
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“The Influence of Body Mass, Training Age and Fighting Stance on Isometric Neck Strength Symmetry of Male Amateur Boxers.”

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ABSTRACT

This study used 102 participants to analyse the influence that body mass, training experience and fighting stance had on the isometric neck strength of male amateur boxers. A MANCOVA analysed allometricly scaled isometric neck strength data, in flexion (FLX), extension (EXT), left lateral flexion (LLF) and right lateral flexion (RLF) across 10 weight divisions. Training experience groups was set as the covariate. A second MANOVA assessed absolute neck strength scores against the boxer's preferred fighting stance. Results across weight divisions highlighted a significant difference in FLX (p = .02) only. No differences were noted between training groups. A Pearson's r produced significant weak negative correlations in FLX and lateral flexion (p = .05). The fighting stance observation highlighted a significant difference (p < .01) in LLF between southpaws and orthodox fighters. Ratio trends also highlighted that southpaws have stronger RLF and orthodox boxers had stronger in LLF. Conclusions: The neck strength of boxers differs among the weight divisions, but only in FLX. General trends indicate heavier boxers have marginally weaker necks. Training age has no impact on neck strength but preferred fighting stance does, especially in lateral flexion. Recommendations: Further research is required on neck responses of the boxer when receiving a punch. By understanding this, practitioners will be able to best utilise the lateral flexion finding. Until such information is available, develop isometric neck strength in FLX and bi-lateral flexion, whilst mainlining strength symmetry is suggested.

Key words: Contact sport, cervical muscle, peak activation.

1.0 INTRODUCTION

Isometric neck strength monitoring and development is important for high impact sports (9,12). Cervical strength literature highlights how neck strength asymmetries can lead to potential injury (2,5). Therefore, by establishing a normative isometric neck strength database, collected information becomes an essential point of biomechanical reference for coaches and medical professionals (16) to lay foundations for athletic advancement and rehabilitation (10,34). Also, it would provide opportunity for statistical understanding of how body mass, training techniques and experience within a sport has the potential to impact on neck strength symmetry. However, one sport that appears absent from the cervical strength discussion is boxing.

Existing boxing research articles have focused on the development of punching power (22,23) as opposed to the fighter's ability to absorb forces to the head. Considering that a peak punch force of 4741 N (31) has been recorded, and both hook and uppercut punches to the jaw can produce head velocities of 3.08 m/s and 2.85 m/s respectively (8), a contextualisation of punch force impact, upon the head and neck of a boxer, emerges. Cervical kinematic and kinetic research has highlighted that isometric pre-tension of the cervical musculature, results in less severe head impact measurements (13,24). This is because an impact to the head of an athlete, with a compliant neck, will expose that individual to experience greater head displacement accelerations and velocities (7). The control of head-neck displacement and reduction of head acceleration, has been associated with improved neck stiffness (2,7,28). Therefore, the development of isometric neck strength should increase the athlete's ability to absorb and dissipate some of the kinetic energy responsible for head acceleration (9,13).

Cervical spine kinematics are complex, they facilitate head movement in flexion (FLX), extension (EXT), left lateral flexion (LLF) and right lateral flexion (RLF). Neck muscles activated in lateral flexion, are bilaterally activated when forced into FLX or EXT (4) and co-activate when redirecting absorbed forces applied to the head (16). Such an interdependency highlights the need for an efficient neck strength symmetry. Correlations ($r = -.50$ to $-.76$, $p < .05$) between neck strength and head acceleration, have associated weaker necks with larger impacts from heading a football (13). Whereas footballers with a more balanced neck strength symmetry have a reduced head acceleration when performing the same task (2,5).

The majority of studies reporting on neck strength symmetries indicate that EXT is stronger than FLX (5,7,11,13,14,16,20,25,33). This should be expected, considering moments recorded on the necks in FLX and lateral flexion are only 58% and 69% respectively of EXT scores (29). The research literature indicates, that the better conditioned the athletes, the more efficient isometric neck FLX to EXT strength ratio appears to be (9,11,15,16). Impacting factors on neck symmetry vary, with body mass (10,15,26), maturation (9,15,16), or exposure to a specific neck strengthening intervention (1,11,25). Strength development, as a by-product of a sport's technical training (33), and specific playing position (20) may also influence cervical symmetry. For example, rugby union forwards possess a lower FLX to EXT ratio than backline players, due to neck activation requirements when scrummaging (20). Unlike team sports, boxing does not have playing positions, however, it does have stance preferences. Boxers can fight out of an orthodox (right handed boxer), or southpaw stance (left handed boxer). Considering the difference in stance requires a difference in head orientation, and encourages the less dominant hand to be used in a jab-punch capacity, it could be beneficial to identify potential trends associating stance with neck symmetry.

Perhaps the greatest influencing consideration, on neck strength, is body mass. Male amateur boxing consists of 10 weight divisions (WD). Research literatures reveals that punch forces received by the head of a test dummy, correlates (r = .54, p = .02) with weight category (31). Therefore, a valid supposition may be drawn that boxers of the heavier WD could have proportionally stronger necks over the lighter boxers, to accommodate greater punching forces. The significance of neck strength to body mass has been observed in a variety of studies with mixed conclusions. For example, lighter professional rugby players outperformed heavier semi-professionals in neck strength tests (11), whereas elite senior wrestlers significantly outperformed their similarly sized elite junior counterparts (33). The authors of the wrestling study suggest that the greater experience and technical training exposure of the senior athletes possibly contributed to the test score difference (33). However, considering there was a five-year difference between the wrestling groups, the issue could also be attributed to maturation.

The maturation argument is further highlighted, when considering high school sport athletes, only have 54% to 73% of the neck strength produced by collegiate athletes (7,16). The investigation of the various influencing variables on body mass, may reinforce the possibility that, any reasonable neck strength to body mass relationship, and efficient symmetrical neck strength ratio, could be influenced by the conditioned state of the athlete (25), and the training environment (1). However, to what extent, the specific impact of training age, technical practice, or fighting stance has on the cervical strength of adult male amateur boxers, remains unmeasured.

Therefore the purpose of this study was to examining neck strength of male amateur boxers. A body mass to strength correlation allows for comparison against body mass to punch force correlations, but more importantly, it may provide support the primary aim, where isometric neck strength was expected to be significantly different between the 10 WD. Secondly, neck strength was expected to be significantly different across training ages. Finally, a significant difference was expected between the two fighting stances. The results of the study should direct practitioners to the importance of an effective development strategy that can focus on the neck strength symmetry of their boxers, not just to identify potential asymmetry issues, but also to understand trends that could be attributed to the technical or physical requirements of the sport. The appropriate application, from such an understanding, may support the athletes in the reduction of head accelerations (5,7).

2.0 METHODS

2.1 Experimental Approach to the Problem

The study was designed to collect data on the isometric neck strength of male amateur boxers. This data was utilised to observe the impact of isometric neck strength between the 10 WD of amateur boxing (weight effect) and on three training experience groups (TEG), the (training age effect). Additionally, data was analysed to highlight possible asymmetry trends across boxing WD and between preferred fighting stances, (Fighting Stance). The Independent variable was WD, set with 10 separate levels, one for each of the boxing weight categories, and a covariate was TEG, set with 3 levels, based on the number of years the individual has been boxing: 0-4 years (0-4y), 5-9 years (5-9y) and 10+years (10+y). Four dependent variables were tested. These were isometric FLX, EXT, LLF and RLF. Prior to the normative data study, a test-retest reliability study, consisting of 10 separate non-boxing participants, was undertaken to assess the consistency and stability of any data recorded by the testing equipment.

2.2 Subjects

The normative data study recruited 102 male subjects (Table 1), from Irish Amateur Boxing Association (IABA) affiliated clubs across the province of Ulster. All participants were registered with the IABA, and fight at club, regional, provincial, or national level. All participants were over 18 years old. The study was approved by the ethics sub-committee of St Mary's University, Twickenham, London. Each participant was presented with a study information sheet, outlining the purpose of the study, and instruction on consent. Volunteers for the research signed a consent form. Prior to testing, participants completed a physical activity readiness questionnaire (PAR-Q), and were excluded if they had a musculoskeletal or orthopaedic injury history to the shoulder, thoracic or the cervical region. Additionally, participants were excluded if they were unable to wear a head harness due to any medical condition. Testing took place over a 5-week period, divided either side of national and regional competitions. This resulted in boxers being close to their fighting weight when tested.

The 10 male volunteers for the reliability study (Table 1) consisted of administrators and individuals recreationally training at the approached boxing clubs. These participants were not registered as an amateur boxer. All reliability study participants were presented with the same study information and followed the PAR-Q and consent protocol as outlined for the normative study volunteers.

TABLE 1. Numbers (n), mean anthropometric characteristics, and mean training experience per amateur boxing weight division for the 102 participants and 10 reliability study volunteers.

			Age (yrs)		Height (cm)		Body Mass (kg)		Training Exp. (yrs)	
Weight Division	**Wt. Limits**	**n**	**Mean**	***SD***	**Mean**	***SD***	**Mean**	***SD***	**Mean**	***SD***
Light Flyweight	46-48.9 kg	2	22.30	4.7	170.00	9.9	50.60*	2.1	7.00	4.2
Flyweight	49-51.9 kg	2	22.75	5.3	160.50*	5.0	49.95*	1.2	6.00	.000
Bantamweight	52-55.9 kg	6	19.50	1.2	171.83*	4.1	55.42*	1.4	5.83	3.1
Lightweight	56-59.9 kg	9	20.20	2.5	173.78*	4.8	59.69*	2.0	4.44	2.7
Light Welterweight	60-63.9 kg	13	22.45	5.2	177.00*	5.7	62.18*	4.3	7.08	5.4
Welterweight	64-68.9 kg	14	20.34	2.8	178.07*	4.9	68.01*	2.8	6.86	3.9
Middleweight	69-74.9 kg	17	25.67	8.2	178.94*	5.7	74.56*	3.8	9.00	5.8
Light Heavyweight	75-80.9 kg	15	23.71	5.4	180.53	7.5	79.34*	3.2	6.67	3.8
Heavyweight	81-90.9 kg	14	24.09	4.2	184.79	7.5	86.38*	3.9	7.14	5.6
Super Heavyweight	91+ kg	10	26.73	7.4	190.40	7.7	100.63	10.1	5.70	6.4
Total		**102**								
Reliability Study	-	10	34.30	8.0	180.10	3.0	88.50	13.4	-	-

* The mean difference is significant at the .05 level when compared to the super heavyweight division.

2.3 Equipment

The test equipment, within this study, was designed and manufactured by the author. A purpose-built frame was constructed with four steel uprights secured by aluminium horizontal and diagonal bracing (Figure 1a). Locking-bolts held the frame in place. Steel L-brackets secured the feet of the uprights to a plywood base for stability. The two front uprights were padded to provide comfort, and torso support for the seated participant during testing. An anchor board was positioned at the rear of the frame. A 5 mm threaded bar, attached to a strain-gauge transducer, was bolted in place along the anchor board (Figure 1b). The transducer used, to measure force application, was a 1 kN DBBSMM series miniature S-beam load-cell (Applied Measurements Ltd., Aldemaston, Berkshire, UK). The load-cell accuracy was $^{+}_{-}$ 0.03%, and it was calibrated to recognise tensile force as the positive output. The load-cell was used in conjunction with a handheld, battery powered, TR150 series digital display load cell indicator (Applied Measurements Ltd., Aldemaston, Berkshire, UK). The peak function was utilised on the display indicator, to highlight the greatest force applied in any single test attempt. This was to the nearest 0.1 N. The displayed force was manually recorded on a data collection sheet.

A 5 mm diameter eye-bolt was also attached to the load-cell (Figure 1c). This facilitated a 3-mm diameter steel cable and a 50-mm carabiner for attachment to the head harness. The anchor board at the rear of the frame had holes positioned at 20 mm centres. This allowed the load-cell to be adjusted vertically to match the height of individual participant (Figure 1d). This ensured that horizontal alignment of the load-cell was within $^{+}_{-}$ 1^{o}. Horizontal length alterations, and the tension of the cable, was fine turned by adjusting the nut, of the threaded bolt attachment, at the anchor board. This was tightened until the test measuring equipment was horizontal and a tension reading of approximately 15 N had been registered.

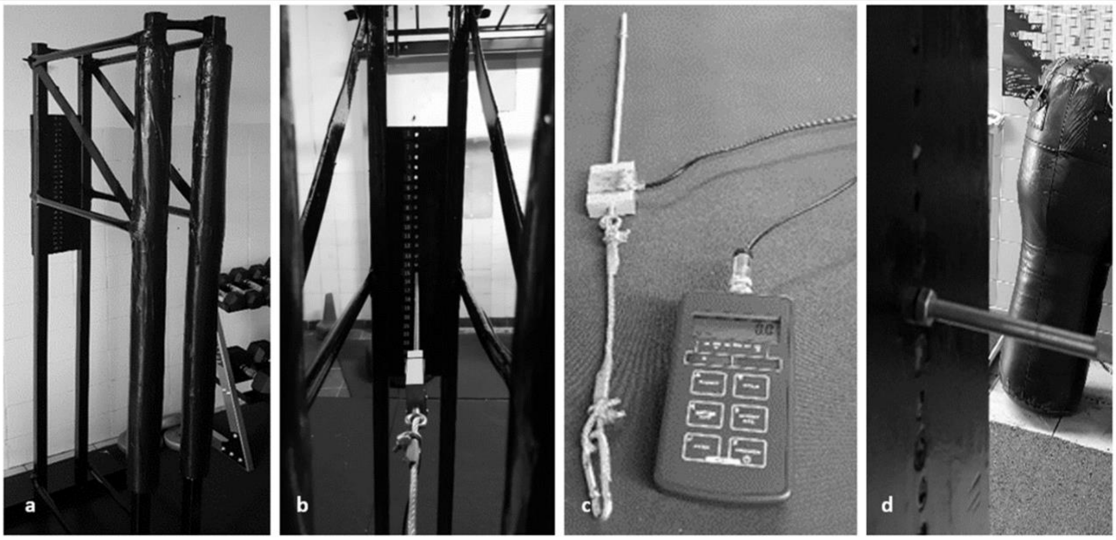

Figure 1. (a) Test frame. b) Threaded bar attachment to anchor board. c) Threaded bar, load cell, display unit, steel cable and carabiner assembly. d) Anchor board height adjustment and threaded bar fixing bolt.

Participants wore a standard neck strength training head harness (Senshi Japan Ltd., Manchester, UK). The harness has 'D' hook attachments, positioned on the circumference strap, to facilitate the 4 test directions. Velcro straps attached under the chin and around the circumference of the head, secured the head harness in position. Alignment of the lower border of the circumference strap with the eyebrow line of the volunteer, ensured that the level of the pulling cable attachment was consistent in all test directions (11). The head was to maintain a neutral anatomical position throughout the procedure (25). Therefore, the participant was instructed to sit upright, and the eyebrow line and chin position were checked for horizontal.

2.4 Procedures

Body mass was measured using Saca Robusta 813 weighing scales (Saca UK, Birmingham, UK) as part of the PAR-Q procedure. Participants provided information of fighting weight category, preferred fighting stance and training experience age, as part of the data collection form. The volunteers were then instructed on the test procedure, and how the equipment should be correctly used.

Participants cleared to participate in the study, performed a pre-test neck, shoulder, and upper back warm-up. This was based on a previous study (26) and consisted of 3 sets of 10 repetitions of vertical shoulder shrugs, shoulder circles (posterior direction arms by the side), scapula retraction / protraction (clasp hands and extend the arms to the front to work through full range of motion), and half circumduction of the neck (in FLX, EXT and lateral flexion). A potentiation sequence, consisting of 2 sets for a 5 second duration hand press into the fore, back and sides of the head, was added. This provided specific preparation for the isometric neck strength test in the 4 desired directions.

During testing, participants were required to sit, in an upright position, with the head in a neutral position, on a box stool that was abutted to the frame. The orientation of the volunteer, in relation to the frame, depended on the direction of isometric neck strength test (Figure 2). This orientation was randomly selected to prevent the potential effects of test sequencing (20). To isolate the neck, 5 cm wide Velcro straps secured the participant's waist and chest to the frame. This limited torso movement. To remove limb involvement, the arms were also strapped to the frame and hands were required to rest loosely on the lap, with palms in a supine position. The feet rested on two separate stability balance discs (25). Once the head harness and cable connection were correctly positioned, the volunteers then provided 3 isometric neck contractions, by pulling against the load-cell, in each of the 4 test directions. The participants had a 3 second countdown to brace, prior to the maximal effort. This reduced the chance for injury to the neck and avoided a shock force being applied to the load-cell. The contraction for each maximal effort lasted for 5 seconds (20,25,26). A 30 second rest between each attempt was provided (13). The timed test duration, and rest period, was digitally pre-recorded to ensure continuity of instruction for each test. A minimum 1 minute rest, between sets, was granted (26), providing opportunity for the volunteer to both recover and reposition themselves for the next test direction. The peak force from each attempt was recorded. Additional trials were required if the covariance of the 3 attempts was greater than 10% (16). The mean score from the 3-maximal peak isometric neck contraction attempts, per direction, was used for statistical calculation (11,13,16).

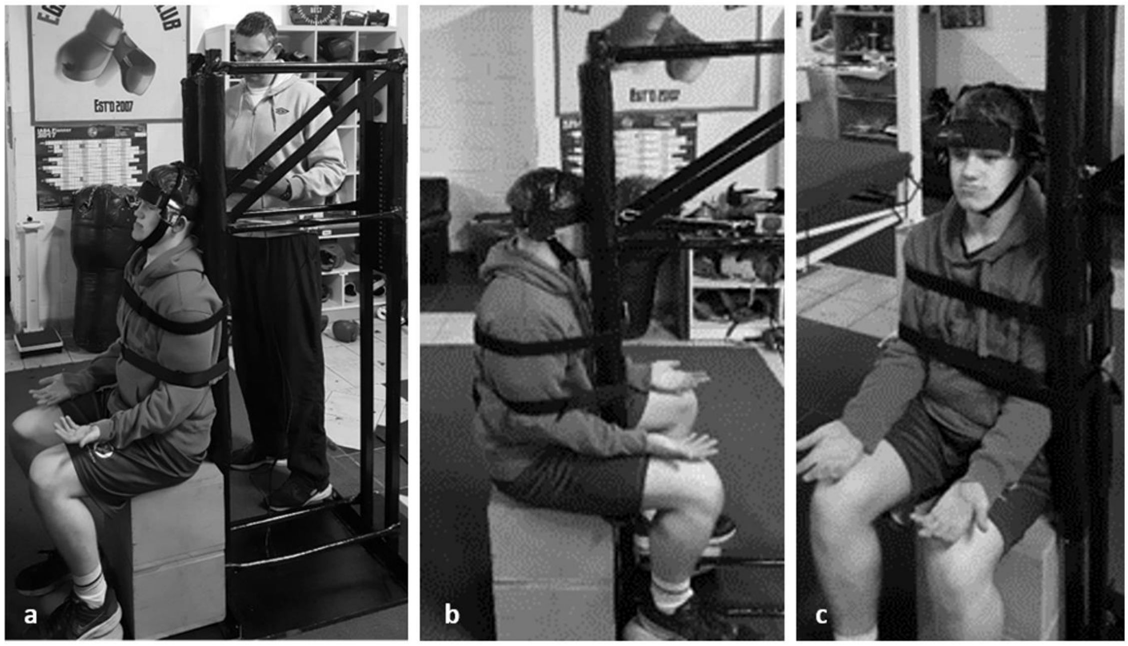

Figure 2. Participant test orientation. a) Flexion. b) Extension. c) Lateral flexion.

2.4.1 Reliability Study Procedures

The 10 recruited reliability study participants performed the described maximal isometric test protocol on two separate occasions, one week apart. The volunteers were discouraged from performing any strength training during the week between tests, and were retested at the same time of the day on both occasions.

2.5 Statistical Analyses

All statistical analyses were calculated using SPSS 24.0 (IBM SPSS Statistics, Armonk, NY) statistical software. An α-level of .05 was set for all tests. Wilks lambda was used to determine the existence an initial joint significant difference in the MANCOVA. Standard deviation (*SD*) was used in conjunction with mean results.

2.5.1 Reliability Study Statistical Analysis

A reliability analysis intraclass correlation coefficient (ICC) determined the significant difference between test-retest data. The 3-attempt mean and maximum scores, for each reliability study participant, was compared. All four-isometric neck strength test directions were analysed.

2.5.2 Normative Data Study Statistical Analyses

The weight effects were calculated using a multivariate analysis of covariance (MANCOVA). This highlighted the statistical differences of the four dependent variables when compared, in an allometricly normalised scale (force / body mass$^{0.67}$), between the WD and TEG groups.

Pearson's *r* correlations were used to compare both absolute and allometriclly adjusted measurements with body mass and adjusted measurements against training experience.

A multivariate analysis of variance (MANOVA) was used to denote potential significant differences, in mean isometric lateral neck strength, relative to fighting stance. A Pearson's *r* correlation was used to compare absolute measurements with training age, and descriptive statistics ratio analysis, on the absolute mean strength scores was used for symmetry observation.

3.0 RESULTS

3.1 Reliability Study

Reliability analysis ICC results indicate that a strong correlation exists, between the two sets of reliability study test data, in both 3-attempt mean and maximum results. The lowest correlation was .90 ($p < .01$) for both maximum and mean scores in EXT. FLX produced mean correlations of .99 ($p < .01$) and a maximal score correlation of .98. ($p < .01$) LLF and RLF score for both mean and maximum score comparisons were .99 ($p < .01$).

3.2 Normative Study

3.2.1 The Weight Effect

The MANCOVA comparison indicated that a significant difference existed when considering WD jointly against the 4 dependent variables, Wilks $\lambda = .56$, F (36, 331.51) = 1.62, $p = .02$, partial $\eta^2 = .14$. Separate consideration of each dependent variable relative to WD provided significant differences for FLX only, F (9, 20.95) = 2.39, $p = .21$.

The post hoc pairwise comparisons in FLX highlight that the flyweight groups was significantly different against all other WD ($p < .05$), except for bantamweights. However, bantamweights were significantly different to welterweight ($p = .04$) and heavyweights ($p = .4$). Finally, light heavyweights were significantly different to welterweights ($p = .03$) and heavyweights ($p = .03$). Mean allometriclly scaled test data per WD is illustrated in Figure 3.

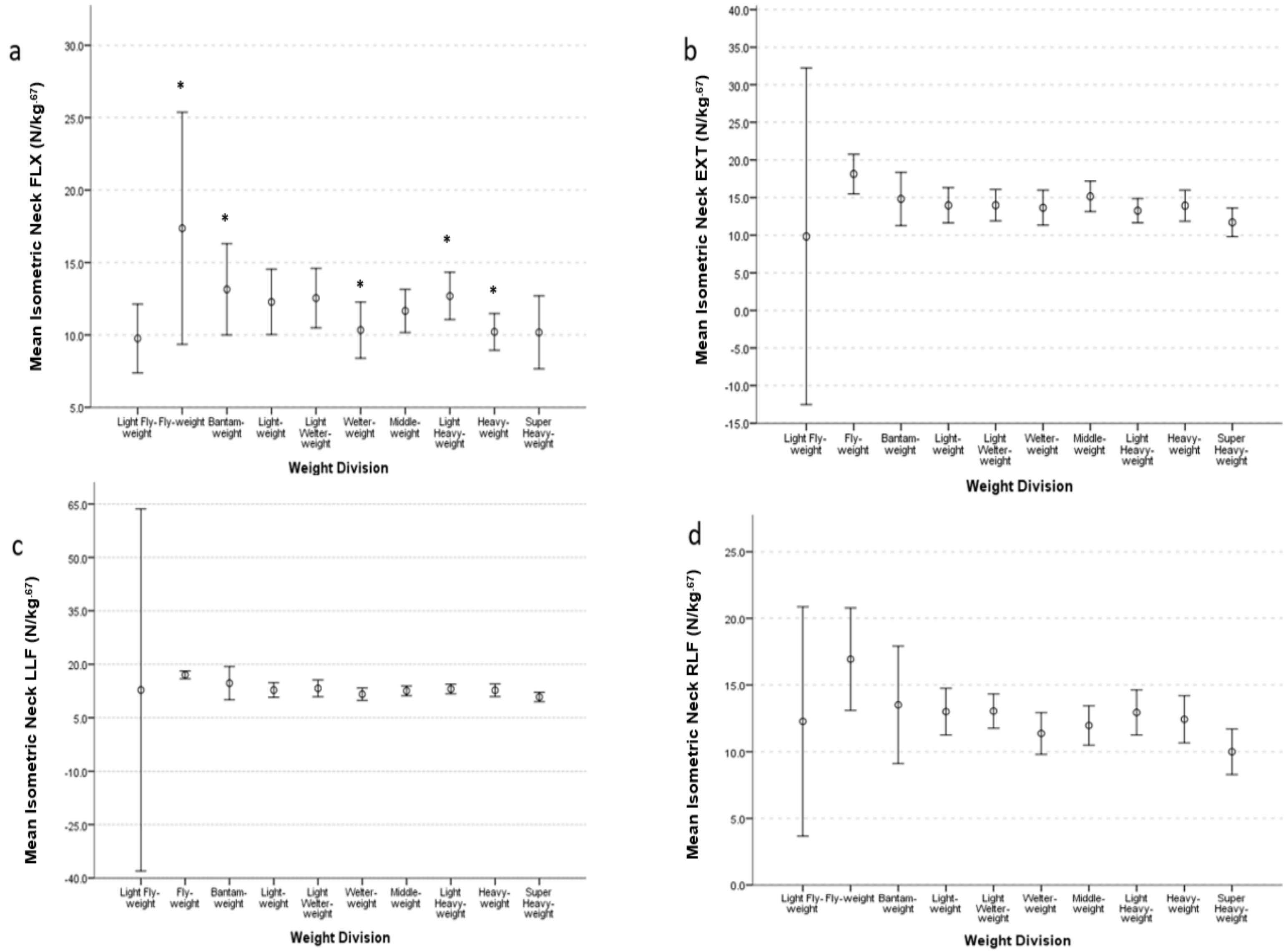

Figure 3. Mean allometric isometric neck peak force and *SD*, per amateur boxing weight division. a) Flexion (b) Extension c) Left lateral flexion d) Right Lateral Flexion. *Significantly different ($p < .05$)

The Pearson's r correlation of allometric scaled isometric neck strength to body mass indicates a weak negative relationship existing in FLX (r = -.20, p = .05), LLF (r = -.20, p = .05) and RLF (r = -.24, p = .01). No significant correlation existed for EXT (p = .17).

The Pearson's r correlation of absolute isometric neck strength to body mass indicates a moderate, positive relationship existing in FLX (r = .28, p < .01), EXT (r = .33, p < .01), LLF (r = . 32, p < .01), and RLF (r = .28, p < .01). The size of the cohort in the correlations, would suggest that these results are not due to random chance.

3.2.2 Training Age Effects

The MANCOVA analysis indicated no significant difference between TEG. (Wilks λ = .93, F (4, 88) = 1.52, p = .21, partial η^2 = .06). Figure 4, provides TEG mean force scores for each test direction.

The Pearson's r correlation of absolute isometric neck strength to training experience age indicates a moderate, positive relationship existing in FLX (r = .22, p = .03), EXT (r = .26, p = .01), LLF (r = .29, p < .01), and RLF (r = .28, p = .01). The size of the cohort would suggest that these results are not due to random chance.

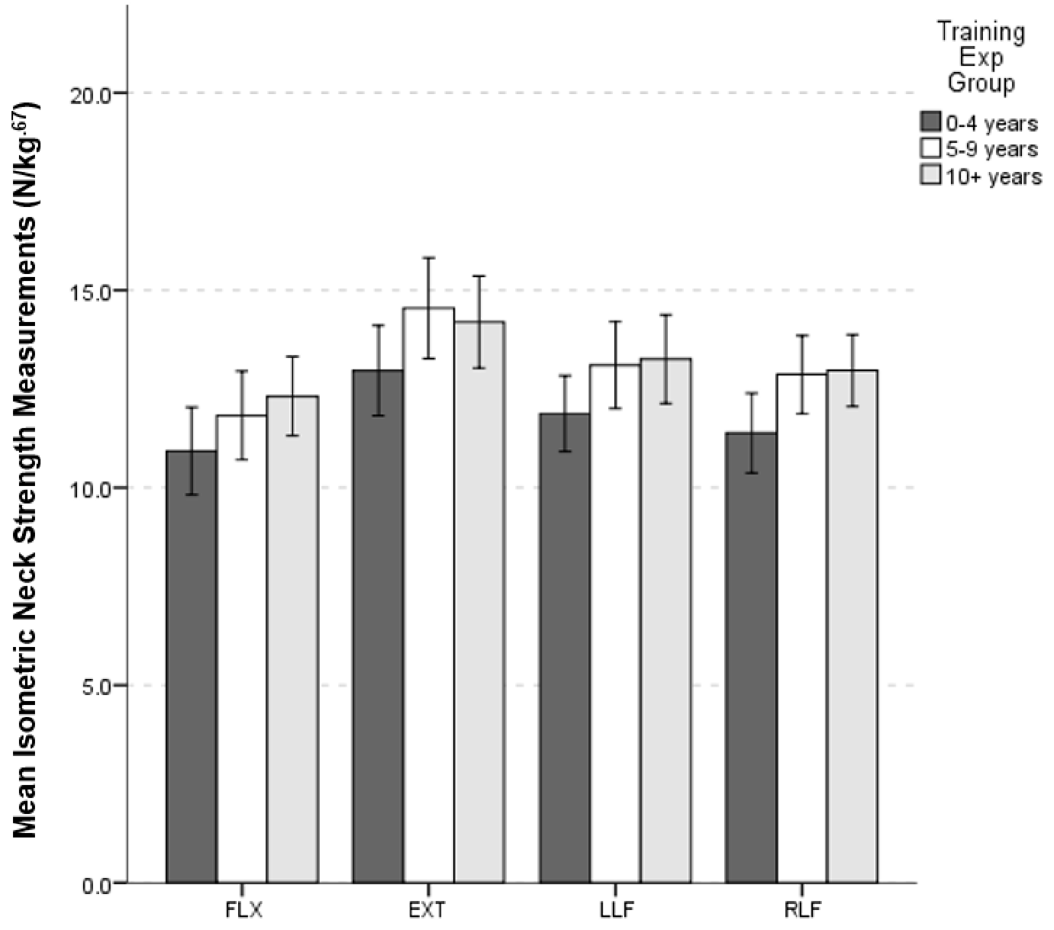

Figure 4. Mean allometric isometric neck strength in FLX, EXT, LLF and RLF for the 3 training experience groups (0-4 years; 5-9 years; 10+ years).
No significant difference exists between groups.

3.2.3 Fighting Stance

A significant difference exists between the two fighting stances. The MANOVA calculated the existence of a significant difference (Wilks λ = .74, F (4, 97) = 8.63, p < .01, partial η^2 = .26). The only significant interaction effect was noted in LLF, where means were recorded as 228.7 N (*SD* = 53.9) for orthodox fighters and 199.2 N (*SD* = 54.4) for southpaws (figure 5).

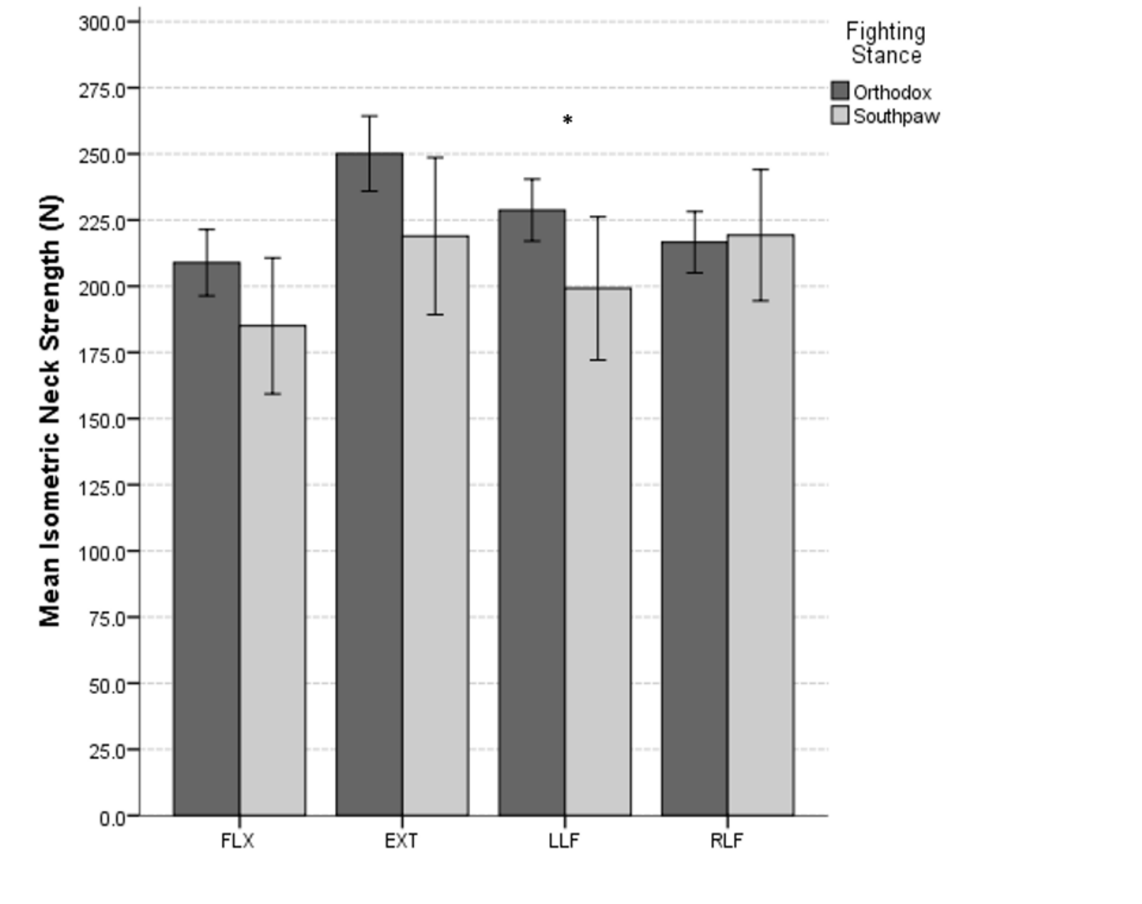

Figure 5. Mean absolute isometric neck strength scores in FLX, EXT, LLF and RLF for the orthodox and southpaw training groups.
LLF is significant between the two groups (*p* = .04).
No cross-test direction statistical comparisons were made.

3.2.4 Symmetry Observation

The overall mean ratios for the 102 participants were .86 (*SD* = .20) for FLX : EXT, 1.04 (*SD* =.13) for LLF : RLF. LLF : EXT ratio was .93 (*SD* = .16) and RLF : EXT was .91 (*SD* = .19). These trends were similar across all TEG and the majority of the WD categories. Only light flyweights differed, scoring 1.02 (*SD* = .23), 1.03 (*SD* = .38), 1.27 (*SD* = .25) and 1.28 (*SD* = .23) respectively for each ratio. Additionally, the LLF : RLF ratio for light-weights was .98 (*SD* = .11) and super heavyweights was 1.11 (*SD* = .11).

Further ratio analysis, with specific regard to preferred fighting stance (Table 2). The ratio scores of the two groups were similar to the overall mean, except where southpaws differed in LLF : RLF (.90, *SD* = .08) and RLF : EXT (1.04, *SD* = .22).

TABLE 2. Left lateral to right lateral flexion ratio, in relation to the boxer's preferred fighting stance. (Fighting stance numbers and percentage breakdown of the 102 participants indicated).

		FLX : EXT		**LLF : RLF**		**LLF : EXT**		**RLF : EXT**	
	n	**Mean**	***SD***	**Mean**	***SD***	**Mean**	***SD***	**Mean**	***SD***
Orthodox	84	.86	.20	1.07	.12	.94	.17	.89	.17
Southpaw	18	.87	.19	.90	.08	.93	.16	1.04	.22
Overall	**102**	**.86**	**.20**	**1.04**	**.13**	**.93**	**.16**	**.91**	**.19**

4.0 DISCUSSION

The MANCOVA indicates the existence of significant differences between WD, but only in FLX. Therefore, the weight effect null hypothesis is rejected. No significant differences were noted between TEG, therefore, the author fails to reject the training effect null hypothesis. Finally, statistical differences were noted between orthodox and southpaw boxers, hence, the fighting stance null hypothesis is rejected.

4.1 Reliability Study

Maximum and mean ICC results from previous isometric neck strength reliability studies, range between .80, classified as good (26) to .99, classified as excellent (10,26,32,33,34). The ICC mean and maximum correlations of this current study matched favourable within this range. The restriction of movement of the participant during testing, both by strapping the volunteer to the equipment frame and limiting neck tilt and rotation during the test, possibly contributes to the high correlation scores. The results provide confidence in the reliability of the testing equipment and procedure used on the amateur boxers.

4.2 Normative Data

4.2.1 The Weight Effect

No apparent research exists on the neck strength of amateur boxers. Therefore, the formation of a normative isometric neck strength database, was intended to provide a profile of neck strength for the sport. The weight effect investigated the relationship of the mean isometric neck strength within and between WD when adjusted allometricly. This was considered important due to the correlation between greater punching forces associated with heavier boxers (31). Statistical significant differences did exist between the 10 WD, but only in FLX. The post hoc analysis highlighted that the light flyweight division differed significantly to all other WD, except flyweight. Additionally, bantamweight and light heavyweights significantly differed with both welter and heavyweights. Clarity of what is significantly different, between and within adjusted WD's, is illustrated in Figure 3.

The variance in *SD* for the light fly-weight division in EXT an LLF, and for the flyweight division in FLX is noticeable. Considering both weight categories only had two volunteers each, is should be appreciated that such a small cohort would not reflect a true representation of the each WD, and therefore, questions the use of this data for a normative database. Nevertheless, the differences between the other WD, in FLX, indicates that both the bantamweight and light heavyweights categories produce greater mean test scores than all other groups, but only significantly greater than the welter and heavyweight categories. The mean score of the last two groups was lower than all other WD.

The general trend of the mean measurements of each WD, per test direction, indicates that the adjusted neck strength of the boxers decreases with an increase in weight class. This pattern is also noted in the allometricly scaled neck strength to body mass correlation, which identifies a significant weak, negative trend in FLX, LLF and RLF. This would suggest that as the boxers get heavier, their normalised neck strength decreases. The size of the cohort used for the correlation would indicate that the significant results are not due to random chance.

Considering a 50.0 kg difference existed between the mean body mass of light flyweight and super heavyweight fighters of this study, the correlation result could be deemed as disconcerting, especially for the heavier boxers. This is because greater punch power was correlated ($r = .54$, $p = .02$) with an increase in body mass (31). Based on the current isometric neck strength literature, this current studies correlation was unexpected. A strong correlation (.46 to .54, $p < .01$) for normalised strength to index of body mass correlation (10) was recorded on healthy public test populations of varying sex. Although this current study used an allometric scale to normalise neck strength, a relevant point was raised in the latter article. It alluded to the expectation of athletes producing a stronger body mass to neck strength correlation, than the non-athletes used within its study (10). Such a correlation was noted in a rugby union cohort investigation that highlighted significant differences between the neck strength tests scores of the heavier forwards ($p < .05$) compared to lighter backline players (14).

Comparing the normalised strength correlation results against an absolute strength correlation demonstrates the importance of the impact of body mass within this boxing study. The conclusions oppose one another as the absolute association indicates a significantly moderate, positive association of neck strength to body mass, thus suggesting that absolute isometric neck strength increases with greater body mass. This relationship was expected, and is similar to other athletic cohort studies (25,29). The influencing effect of body mass is further highlighted when attempting inter-literature comparisons with absolute scores. The highest mean test score, across the WD, for each test direction was recorded by the flyweight category in FLX and by heavyweights in the other three test directions. These scores compare favourably with physically active adults (28) and pre-intervention scores for recreationally active adolescent males (9). Unfortunately, the boxing scores differed to the other contact sports of wrestling (33) and rugby union (11,14,25), where the boxer’s isometric cervical strength measurements range from 36% to 86% of the recorded results of the other studies. Considering the punch force, of super heavyweight boxers, can exceed 4700 N (31), only having a neck strength that corresponds to physically active adults, may be considered as underprepared. However, practitioners should be cautious when directly comparing neck strength literature, as a lack of standardisation exists between isometric neck strength testing protocols (12,27). For example, the difference in EXT, between two professional rugby union studies, was 511.9 N (4,11). This difference was potentially due to testing equipment and participant positioning. The first article used a fixed tension load-cell for participants to pull against, whilst lying down, strapped to a bench (4). The second study used a hand-held dynamometer to pull against the head of the participant whilst seated (11). Both instruments were declared as valid within each study. Therefore, to compare between studies, one should view beyond the test results and consider test protocol similarities.

One professional rugby study did follow similar testing protocols to this current boxing study (25). A result comparison indicates that the boxer's neck strength was between 65% and 86% of the rugby players, across the four test directions. However, the average weight of the rugby players was 102 kg and the boxers 73.6 kg, thus highlighting the issues of comparing absolute strength scores across various studies, and justifying the need for body weight adjusted strength scores. Despite this, the comparison did introduce two new consideration factors: First, this is a comparison between professional and amateur sports; secondly, the rugby players had just completed a specific neck strengthening intervention. This latter factor may be an influencing issue that could impact within the individual WD results of the boxers. It was possible that some boxers, within this study, were on an existing neck strengthening programme. The fighting abilities of the volunteers, in this study, ranged from inter-club boxers to individuals on specific IABA elite programmes. This current research did not distinguish between the standard of the fighters, or question boxers about specific neck strengthening programmes. Individuals on an effective neck strengthening programme may skew the results towards the upper limits of a group mean, as structured training programmes can make such individuals more homogeneous (1). Future research, on the neck strength differences between fighting abilities, and identification of individuals on specific neck strength programmes, is suggested, to rectify this limitation.

Although the MANCOVA only highlighted that significant difference existed in FLX, one should also be aware that Figure 3(b, EXT) could be potentially indicating conflicting results to the MANCOVA. The position of the light flyweight mean and the *SD*, relative the other weight categories, may indicate that a significant difference could exist in EXT. The author is unsure whether the difference between the graph and statistical calculation is a consequence of the participant numbers in the two lightest weight divisions, or whether it is a result of the large number of variables being analysed within the MANCOVA creating a statistical error. As such, further statistical investigation is recommended to simplify the calculation.

4.2.2 Training Age Effect

It was previously highlighted that the neck strength of sports athletes can improve, as a consequence of technical training experience, albeit due to their seniority (33), playing position (11,20), or maturation (7,16). Understanding such differences, between the boxing TEG, may highlight whether an impact, from a greater accumulation of training experience exists. The training age effect compared the isometric neck strength differences between the boxers when categorised in TEG. Although the absolute isometric neck strength to training age correlation indicated an increase in isometric neck strength with advanced boxing experience, the allometriclly scaled MANCOVA comparisons indicated that no significant differences existed between the 3 TEG (figure 4). The correlation result and mean TEG scores do concur with one another, highlighting, that the least experienced group only produced between 85% to 91% of the isometric neck force delivered by the most experienced boxers, and 88% to 92% of the force produced by the middle group, across the four dependent variables.

It is unlikely that maturation has impacted on the neck strength of boxers. This is despite 35.7% of the 10+y group participants being 22 years old or younger, meaning that they were 12 years old or less when they started boxing. It is accepted that greater cervical force is generated with advancements in maturity (21) where EXT strength can increase by 36% between the ages of 14 and 18 (15). However, 60.0% of the 5-9y and 79% of the 0-4y groups were also 22 years old or younger. This means that the greater number of mature boxers (64.3%) were within the 10+y group. However, considering the non-significant difference that exists between the 3 TEG, it appears that the necks of the 10+y group did not gain any strength advantage by going through the maturation process whilst boxing.

The impact of isometric neck strength from the technical training of boxing is also unknown. In other contact sport the neck strength to sport relationship is perhaps more obvious. For example, wrestling has specialist exercises that require pushing and pulling on the head that is believed to impact on neck strength (33), or in rugby union where playing position can influence neck strength, where forwards have been noted to have a reduced FLX to EXT ratio critical for the scrummaging stability (20). The impact of a different fighting position on neck strength is discussed in the symmetry observation section. However, in relation to training age, the results do not suggest that the training age and experience of the boxers in this study provide any cervical strength advantage.

4.2.3 Symmetry Observations

Providing a more effective and symmetrical neck balance may reduce the potential for cervical injury (5,13). The mean FLX : EXT ratio across all amateur boxing WD was .86. This result highlights the better mechanical advantage that the neck extensor muscles have over flexors, both in producing a greater maximal moment (29), and having the larger cross-sectional area that is essential for postural stability (26). The WD mean ratio compares favourably with the .55 to .75 ratio range produced in professional rugby union studies (11,14,25). Although this does not highlight stronger neck FLX, it may, however, indicate the higher FLX contribution required for boxing. Unfortunately, there is a dearth of biomechanical research on the impact reactions of a boxers head from a punch, but studies on heading an association football has indicated that a FLX : EXT balance provides for more efficient head acceleration control, essential for injury reduction (5). Athletes with weaker necks and greater strength imbalances are less efficient at mitigating the head accelerations created from heading a football (13). However, it must be understood that heading a football is a deliberate action unlike receiving a punch in boxing. Nevertheless, the boxers could have developed greater FLX control from involvement in the sport. Interestingly the ratio scores of the 5-9y TEG was .81, whereas the 10+y group was .87. This difference was similar to a trend noted between senior and junior elite wrestlers (33). That trend drew the conclusion that the more efficient FLX : EXT ratio, of the senior wrestlers, was gained from the specific contribution of the sport developing FLX strength (33). However, it must be stressed that there is no statistically significant difference in either FLX or EXT between any of the three TEG groups.

The mean lateral flexion to EXT ratios across the 10 WD and the 3 TEG provided reasonable symmetry. These ratios indicate that on average the boxers are stronger in EXT than in FLX, or either lateral flexion. The results were expected considering the co-activation of bi-lateral muscles are required in forced EXT (4). Direct comparison of bilateral flexion provided a reasonable symmetry between all WD. The LLF : RLF ratio was 1.04. Thus suggesting that LLF was slightly stronger than the right side. Initially this did not appear unusual. However, nine of the 10 WD and all 3 TEG, did indicate a stronger left side of neck where one of these categories, super heavyweight, provided an unexpected high ratio of 1.11. The reason for this imbalance of ratio was that 64.7%, of the boxers provided measurements suggesting they were stronger on the left side. Therefore it was plausible that boxing naturally creates a lateral cervical flexion strength imbalance.

4.2.4 Fighting Stance

The only significant difference discovered between the neck strength measurements of the two fighting stance groups was in LLF. The mean bi-lateral ratio, for the 84 orthodox boxers, was 1.07, indicting a stronger left side of neck. The mean ratio for the 18 southpaw fighters was .90, indicating a stronger right side of the neck. The LLF : RLF ratios, within each fighting stance may suggest that a unilateral neck strength improvement is being inadvertently developed as a bi-product of a preferred fighting stance. Whether this is enhanced from an eccentric control when absorbing an impact blow to the head, or from defence techniques, where anticipation and bracing for impact is creating a unilateral neck muscular activation, or even development from a kinetic chain transfer, through frequent jab-punching with the less dominant hand, is unknown. Therefore it is proposed that further is investigation is required to establish causation. A second interesting ratio trend existed for southpaws and the RLF : EXT score (1.04), that could suggest on average, the group is stronger in RLF than in EXT. This relationship was non-existent for orthodox boxers in relation to their LLF : EXT ratio (.93). A possible causation for the difference between the respective fighting stance's lateral to EXT ratio strength difference could be the strength of the orthodox boxers in EXT. Although not directly cross-calculated, figure 5 does suggest that a potential significant difference exists between the orthodox EXT strength score and LLF strength score. This is not the case for the southpaw EXT and RLF scores. Although the difference between the two stances in EXT was not significant, the mean difference between the two groups (31.12 N) was large enough to impact on the EXT to lateral flexion ratio results. What this means for the boxers is unknown as further analysis is required to discover the significance of the lateral flexion to EXT measurements. However, until further research resolves this issue, it could be prudent to attain a balanced neck symmetry as outlined in association football heading studies (5,13) to contribute to the control of impact induced head acceleration, and, from a practical understanding, to prepare the boxers for punches to either side of the head.

This study attempted to establish whether body mass, training age and fighting stance had an influence on the isometric neck strength symmetry of male amateur boxers. The normalised weight effect highlighted that significant differences existed in FLX between the WD. The normalised isometric neck strength correlation did indicate that neck strength marginally decreased with an increase in body mass, certainly in relation to FLX, and lateral flexion. However, it did not establish the contribution that body mass has on the development of neck strength. The reason for this not fully understood, and may require further research. The use of this data as a normalised database can be questioned. This is because of the difference between WD cohorts numbers may negatively impact on the overall test results.

Although the training effect did not show any significant differences between the 3 TEG, the symmetry observation suggested that boxers appear to have a more balanced FLX : EXT ratio than indicated in previous studies on other test populations. It remains unclear if the more efficient FLX : EXT balance highlighted in this study is a direct adaptation from boxing, or is a result created from a variance of test procedure when compared to others studies. Either way, the lack of significant difference between the three TEG groups would suggest that possessing greater boxing experience does not provide an advantage to greater neck strength.

The fighting stance comparison highlighted significant differences existing between groups in LLF. Ratios results indicate that orthodox boxers are stronger in LLF and southpaw boxers are stronger in RLF. Reasons for the difference require further investigation, but considering head accelerations are more efficiently controlled by stiffer and balanced neck strength (28), the deliberate enhancement of this imbalance neck strength would be unadvisable.

5.0 PRACTICAL APPLICATION

Due to the lack of information surrounding the neck strength of amateur boxers, an intention of this study was to provide a normative database for comparison between WD. The author does recommend the use of an allometric scale to normalise strength to body mass to allow for easier comparisons between isometric neck strength researches, but also stresses that the underlying standardisation issues when collecting the initial data will naturally impact on adjusted results. Additionally, any such comparisons should be viewed with an understanding of the test protocol standardisation differences that exist.

This study did use ratios as a means for comparison between studies, but this was for symmetry purposes only. The author would still encourage and support the measuring and monitoring of neck strength in various directions for boxers, especially in light of the lateral flexion and fighting stance trends. Although this study highlighted that boxing involvement appears to influence strength in FLX, and more specifically, lateral flexion, the causation of this is not fully understood. Further research is required into the biomechanics of the head and neck of boxers prior to, during and after punch impact. This may provide better understanding for athlete programming recommendations especially in relation to a choice between lateral flexion symmetry or a deliberate asymmetry. If the lateral flexion imbalance noticed in this study is a result of an eccentric control of a punch then a deliberate asymmetric neck strengthening programme could be recommended. However, until this is proven, it may be prudent for the strength and conditioning practitioner to focus on enhancing the FLX and bi-lateral strength of their boxer, whilst striving to simultaneously develop symmetry. This is because the maintenance of neck symmetry may reduce the potential for neck injury (5,13), and improved neck strength may attenuate the dynamic reaction of the head from imposed forces (7).

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Appendix A - Ethics Application and Approval

A.1. Ethics Application Form

St Mary's University Twickenham London

St Mary's University

Ethics Sub-Committee

Application for Ethical Approval (Research)

This form must be completed by any undergraduate or postgraduate student, or member of staff at St Mary's University, who is undertaking research involving contact with, or observation of, human participants.

Undergraduate and postgraduate students should have the form signed by their supervisor, and forwarded to the School Ethics Sub-Committee representative. Staff applications should be forwarded directly to the School Ethics Sub-Committee representative. All supporting documents should be merged into one PDF (in order of the checklist) and clearly entitled with your **Full Name, School, Supervisor.**

Please note that for all undergraduate research projects the supervisor is considered to be the Principal Investigator for the study.

If the proposal has been submitted for approval to an external, properly constituted ethics committee (e.g. NHS Ethics), then please submit a copy of the application and approval letter to the Secretary of the Ethics Sub-Committee. Please note that you will also be required to complete the St Mary's Application for Ethical Approval.

Before completing this form:

- Please refer to the **University's Ethical Guidelines**. As the researcher/ supervisor, you are responsible for exercising appropriate professional judgment in this review.
- Please refer to the Ethical Application System (Three Tiers) information sheet.
- Please refer to the Frequently Asked Questions and Commonly Made Mistakes sheet.
- If you are conducting research with children or young people, please ensure that you read the **Guidelines for Conducting Research with Children or Young People**, and answer the below questions with reference to the guidelines.

Please note:

In line with University Academic Regulations the signed completed Ethics Form must be included as an appendix to the final research project.

If you have any queries when completing this document, please consult your supervisor (for students) or School Ethics Sub-Committee representative (for staff).

St Mary's Ethics Application Checklist

The checklist below will help you to ensure that all the supporting documents are submitted with your ethics application form. The supporting documents are necessary for the Ethics Sub-Committee to be able to review and approve your application.

Please note, if the appropriate documents are not submitted with the application form then the application will be returned directly to the applicant and may need to be re-submitted at a later date.

	Enclosed? (delete as appropriate)		Version No
Document	Yes	Not applicable	
1. Application Form	Mandatory		
2. Risk Assessment Form	Y		
3. Participant Invitation Letter	Y		
4. Participant Information Sheet	Mandatory		
5. Participant Consent Form	Mandatory		
6. Parental Consent Form		N/A	
7. Participant Recruitment Material - e.g. copies of Posters, newspaper adverts, website, emails		Not required letters handed out at club	
8. Letter from host organisation (granting permission to conduct the study on the premises)	Y		
9. Research instrument, e.g. validated questionnaire, survey, interview schedule	Y		
10. DBS (to be sent separately)		N/A	
11. Other Research Ethics Committee application (e.g. NHS REC form)		N/A	
12. Certificates of training (required if storing human tissue)		N/A	

I can confirm that all relevant documents are included in order of the list and in one PDF document (any DBS check to be sent separately) named in the following format: ***Full Name, School, Supervisor.***

Signature of Applicant:

Signature of Supervisor:

St Mary's University Twickenham London

Ethics Application Form

1) Name of proposer(s)	Kevin Gallagher
2) St Mary's email address	125555@live.stmarys.ac.uk
3) Name of supervisor	Dr Dan Cleather

4) Title of project 'Isometric Neck Strength Symmetry and Correlation with Body Mass of Male Amateur Boxers.'

5) School or service	School of Sport, Health and Applied Sciences
6) Programme (whether undergraduate, postgraduate taught or postgraduate research)	Postgraduate MSc In Strength & Conditioning
7) Type of activity/research (staff/undergraduate student/postgraduate student)	Postgraduate

8) Confidentiality	
Will all information remain confidential in line with the Data Protection Act 1998?	YES

9) Consent	
Will written informed consent be obtained from all participants/participants' representatives?	YES

10) Pre-approved protocol	

Has the protocol been approved by the Ethics Sub-Committee under a generic application?	NO

11) Approval from another Ethics Committee	
a) Will the research require approval by an ethics committee external to St Mary's University?	No
b) Are you working with persons under 18 years of age or vulnerable adults?	No

12) Identifiable risks	
a) Is there significant potential for physical or psychological discomfort, harm, stress or burden to participants?	NO
b) Are participants over 65 years of age?	NO
c) Do participants have limited ability to give voluntary consent? This could include cognitively impaired persons, prisoners, persons with a chronic physical or mental condition, or those who live in or are connected to an institutional environment.	NO
d) Are any invasive techniques involved? And/or the collection of body fluids or tissue?	NO
e) Is an extensive degree of exercise or physical exertion involved?	YES
f) Is there manipulation of cognitive or affective human responses which could cause stress or anxiety?	NO
g) Are drugs or other substances (including liquid and food additives) to be administered?	NO
h) Will deception of participants be used in a way which might cause distress, or might reasonably	NO

affect their willingness to participate in the research? For example, misleading participants on the purpose of the research, by giving them false information.	
i) Will highly personal, intimate or other private and confidential information be sought? For example sexual preferences.	NO
j) Will payment be made to participants? This can include costs for expenses or time.	NO
k) Could the relationship between the researcher/ supervisor and the participant be such that a participant might feel pressurised to take part?	NO
l) Are you working under the remit of the Human Tissue Act 2004?	NO

13) Proposed start and completion date
Please indicate: • When the study is due to commence. • Timetable for data collection. • The expected date of completion. Please ensure that your start date is at least 3 weeks after the submission deadline for the Ethics Sub-Committee meeting.
Data collection is timetabled from 9/1/17 to 22/1/17. Dissertation submission date 21/5/17 Post per review resubmission date 18/6/17 Poster presentation and study defence June/July 2017 - TBC

14)Sponsors/Collaborators
Please give names and details of sponsors or collaborators on the project. This does not include your supervisor(s) or St Mary's University. Sponsor: An individual or organisation who provides financial resources or some other support for a project.

- Collaborator: An individual or organisation who works on the project as a recognised contributor by providing advice, data or another form of support.

No individual / organisation provides a financial resource to this study.

Eglington Amateur Boxing Club is providing the testing facility. (Letter of approval from Jim Knox, club secretary, is attached after the Participant Consent Form)

15. Other Research Ethics Committee Approval

- Please indicate whether additional approval is required or has already been obtained (e.g. the NHS Research Ethics Committee).
- Please also note which code of practice / professional body you have consulted for your project.
- Whether approval has previously been given for any element of this research by the University Ethics Sub-Committee.

No additional approval is required or obtained.

Section 17 (Methodology) outlines previous academic research that was used to formulate the study test protocol.

No previous approval has been sort

16. Purpose of the study

In lay language, please provide a brief introduction to the background and rationale for your study.

Purpose of the Study: Information on punching power within boxing, and how it correlates with body weight is well documented. However, information relating to a boxer's ability to absorb a punch is under investigated. Research in other contact sports have focused on neck strength as being critical to absorbing forces to the head. Therefore, this study will initially investigate the reliability of the neck strength test protocol and testing equipment used within this study. Once reliability has been confirmed, the study will focus on the primary objective of collecting neck strength data across a variety of adult amateur boxing weight categories for comparison between the weight divisions, boxing training experience and against neck strength study data from other sports. This will also provide base line neck strength statistics for strength and conditioning coaches working within boxing.

The Study's Findings: It is the intention of the reliability study to accurately note stable and consistent data from repeat testing of the same group of individuals (10 number) to provide confidence in the primary study data collection. The results of the primary study are to be examined to understand:

- Isometric neck strength symmetry patterns (left verses right side and forward verses backwards) within each weight category.
- Neck strength patterns between weight categories.
- Neck strength patterns based on the boxers training experience.
- Compare the isometric neck strength results of boxers against other sports.

17. Study Design/Methodology

In lay language, please provide details of:

a) The design of the study (qualitative/quantitative questionnaires etc.)

b) The proposed methods of data collection (what you will do, how you will do this and the nature of tests).

c) You should also include details regarding the requirement of the participant i.e. the extent of their commitment and the length of time they will be required to attend testing.

d) Please include details of where the testing will take place.

e) Please state whether the materials/procedures you are using are original, or the intellectual property of a third party. If the materials/procedures are original, please describe any pre-testing you have done or will do to ensure that they are effective.

Answer a)

- This is a quantitative study, where isometric neck strength in flexion, lateral flexion and extension will be measured, cross examined and categorised per body mass and boxing experience for reporting.
- Therefore, all information required is either recorded on the PAR-Q health check sheet or is recorded on the strength test data sheet (copies of each form are provided at end of this Ethics Application).

Answer b)

Test Procedure

After completion of the PAR-Q form and clearance to proceed the participant will perform the following:

- Warm-up
  - Shoulder mobilisation (3 x 10 reps of shoulder shrugs, circle movement of shoulder & shoulder retraction /protraction (as outlined by Salmon, Handcock, Sullivan, Rehrer and Niven, 2015).
  - Additional controlled neck movements in flexion, bilateral flexion, transverse rotation, and hyper-extension. 10 reps each direction.
  - Finally, pressing the head into the hand for 5 seconds in each of the 4 directions mentioned for potentiation.
- Test protocol
  - The procedure will be explained to the participant
  - The participant will be positioned as outlined in the 'Participant Set-up Position' below.
  - The participant will then preform an isometric neck contraction neck in the desired direction. (the direction order will be randomised to take fatigue into account). This will be using the equipment as outlined in the 'Equipment used' section below.
  - 3 attempts in each direction will be granted. The peak mean score from each attempt will be used (as outlined by: Geary, Green and Delahunt, 2013; Gutierrez and Conte, 2014; & Hildenbrand and Vasavada, 2013).

    - Contraction duration should last for 5 seconds (Konraith and Appleby, 2013; Naish, Burnett, Burrows, Andrews and Appleby, 2013 & Salmon, Handcock, Sullivan, Rehrer and Niven, 2015).
    - Rest between direction sets shall be a minimum of 1 minute (Salmon, Handcock, Sullivan, Rehrer and Niven, 2015).

Participant Set-up Position (ensure comfort and safety; head starts in neutral alignment and restriction of body movement to isolate the neck as much as possible):

- The participants will be sat upright on a bench against a purpose built padded frame. The head will rest against the frame in a neutral position.
- The chest (when testing neck extension), back (testing neck flexion) or side of the torso (when testing for lateral flexion) will also rest against the padded frame.
- The participants will be strapped (using 50 mm wide 'Velcro' strapping) at the chest and waist.
- Feet will be resting on tip toes (Alricsson et al, 2004).
- Arms will be folded across the chest, with finger tips touching the shoulders.

Equipment used (See photographs provided at end of application):

- A 'Senshi Japan Ltd.' head harness.
    - This is manufactured with D hooks positioned around the harness to facilitate for free and cable weight training in the various test directions.
    - The straps are positioned around the circumference of the head and over the top of the head. An adjustable chin strap is used to tighten the harness into the correct position and prevent slippage during movement.
- Purpose built frame.
    - 70 cm long x 35 cm wide x 180 cm high iron frame with aluminium bracing will be used to:
        - Position the bench against the the front of the frame for the participant to brace against
        - Anchor the load testing equipment to the rear of the frame.
    - The frame is padded at the front for the comfort and protection of the participant
    - Several eye bolts are vertically spaced at 20 mm centres at the rear of the frame. This allows for the load testing equipment to be adjusted to match the height of the participant and will ensure that the horizontal angle of the equipment remains within the accuracy tolerance is $^{+}$-2°.

- Measuring equipment.
    - 1000 N S-Beam compression / tension load cell is to be used. The test will utilise tension.
    - The participants will exert tension on the load cell, therefore, tension will be a positive reading.
    - Load cell accuracy is $^{+}$- 0.03%
    - Load cell attachment eye bolts were also supplied
- Digital display equipment
    - 'TR150 series' handheld digital display
    - Calibrated in Newtons
    - Displays to 0.1 N.
- Cables and attachments
    - Stainless steel carabiners are used to attach the cable to the head harness, load cell, and anchor point of the frame.
    - Cable length will allow for no slack in the equipment from anchor point through to head harness, where the participant is seated with head in a neutral position.
    - All cables and attachments are designed to withstand a minimum 1000 N load

Answer c)

- The whole testing procedure, from warm-up to last isometric attempt, will be completed in a single 25-minute booking.

- Participants involved in the reliability study will be asked to repeat the testing protocol. This reliability tests will be performed 1 week apart.

Answer d)

- The study will take place at Eglington Boxing Club, Unit 21, Vale Centre, Greysteel, Clooney Road, Co. Derry, BT47 3GE (confirmation letter for Jim Knox, club secretary, is attached after the Participant Consent Form)

Answer e)

- All load cell and digital display equipment was manufactured and supplied by 'Applied Measurements Ltd.' Berkshire. The head harness is bought from local gym outfit specialists and manufactured by 'Senshi Japan Ltd.'. The frame is personally built.

- A reliability study of 10 volunteers performing the test protocol and repeating 7 days later will be performed prior to the main study testing. Any significant difference of test results (greater that 5% difference between 1st & 2nd test), that cannot be justified, will deem the test not reliable.

- Testing procedures are formulated around numerous academic articles and have been indicated within the test procedure section above.

18. Participants

Please mention:

a) The number of participants you are recruiting and why. For example, because of their specific age or sex.
b) How they will be recruited and chosen.
c) The inclusion/exclusion criteria.
d) For internet studies please clarify how you will verify the age of the participants.
e) If the research is taking place in a school or organisation then please include their written agreement for the research to be undertaken.

Participant numbers:

- 100 minimum

(This number allows for a significant number of participants per weight category)

- Male boxers
- Over 18 years old

Recruitment:

Letters will be handed out at boxing clubs. The letter will have the participant information sheet and consent sheet attached. Once a participant fully understands the criteria and procedures as outlined on the information sheet, and is willing to participate, I will request they complete the consent form. A copy of their completed consent form will be given to them for their records.

- Interested volunteers will be provided a date and time for testing
- Research is not being done for any individual club or organisation. All participants are individuals that freely volunteer to take part in the study.
- This is not an internet study.
- Participants will be excluded from the study if they have a history of previous neck injury or neck pain.

19. Consent
If you have any exclusion criteria, please ensure that your Consent Form and Participant Information Sheet clearly makes participants aware that their data may or may not be used. a) Are there any incentives/pressures which may make it difficult for participants to refuse to take part? If so, explain and clarify why this needs to be done. b) Will any of the participants be from any of the following groups? ➢ Children under 18 ➢ Participants with learning disabilities ➢ Participants suffering from dementia ➢ Other vulnerable groups. c) If any of the above apply, does the researcher/investigator hold a current DBS certificate? A copy of the DBS must be supplied **separately from** the application. d) How will consent be obtained? This includes consent from all necessary persons i.e. participants and parents.
a) No b) No c) N/A all consenting adults d) Letters will be handed out at boxing clubs. The letter will have the participant information sheet and consent sheet attached. Once a participant fully understands the criteria and procedures as outlined on the information sheet, and is willing to participate, I will request they fill in the consent form. A copy of their completed consent form will be given to them for their records.

20. Risks and benefits of research/ activity
a) Are there any potential risks or adverse effects (e.g. injury, pain, discomfort, distress, changes to lifestyle) associated with this study? If so please provide details, including information on how these will be minimised. b) Please explain where the risks / effects may arise from (and why), so that it is clear why the risks / effects will be difficult to completely eliminate or minimise. c) Does the study involve any invasive procedures? If so, please confirm that the researchers or collaborators have appropriate training and are competent to deliver these procedures. Please note that invasive procedures also include the use of deceptive procedures in order to obtain information. d) Will individual/group interviews/questionnaires include anything that may be sensitive or upsetting? If so, please clarify why this information is necessary (and if applicable, any prior use of the questionnaire/interview).

e) Please describe how you would deal with any adverse reactions participants might experience. Discuss any adverse reaction that might occur and the actions that will be taken in response by you, your supervisor or some third party (explain why a third party is being used for this purpose).

f) Are there any benefits to the participant or for the organisation taking part in the research (e.g. gain knowledge of their fitness)?

Answer a)

- The study is collecting data by testing neck strength, as such, there will be a possibility of muscle or soft tissue injury. However, the risks of taking part in the study are no greater than they would be if taking part in a normal neck strengthening training session. To minimise potential injury risk, the testing procedure will follow good practice procedures. This is as follow:

- Completed risk assessment.
- Medical history questionnaire for participants.
- Ensure the participant fully understands the testing procedure (This will include a practice if required by the individual).
- Thorough warm-up to the neck & shoulders.
- Correct muscle contraction duration.
- Appropriate rest between contraction attempts.
- Correct use of the testing equipment and accessories as outlined by the manufacturer.
- Testing will be supervised by the researcher
- A qualified first aider will be present throughout testing
- The proposed methods of testing have been compiled following good practice from similar academic research and testing equipment manufacturer's guidelines.

Answer b)
Frame Stability:

- Naish et al (2013) outlined the importance of the immovability of the frame in providing both safety to the participant and accuracy of test results. Therefore, the frame in this study is bolted to a stable flat surface and horizontal and diagonal restraints are positioned to endure rigidity (see pictures attached).

Potential for neck injury:

- Any maximal muscle assessment has the potential for injury. Although this risk cannot be fully eliminated, the potential neck injury risk was controlled in the following articles:

- Hamilton et al (2012) reduced the potential risk of neck injury by limiting head rotation and testing neck strength along anatomical lines.
- Any participant with a history of neck pain was refused permission to take part in the study (Geary, 2014 and Ylinen et al, 2003).
- Naish et al (2013) outlined the importance of a firm fitting of the head harness to the head provide both safety to the participant and accuracy of test results. The head harness selected for this study is specifically manufactured for resistance training the neck through flexion, extension, and bilateral flexion. (supplier 'Senshi Japan Ltd.')
- Hildenbrand and Vasavada (2013) highlight how strapping the volunteers in a seated upright position provides lumbar support for the participants.
- Warm-up protocols were used prior to neck strength testing by Geary et al (2014), Salmon et al (2015) and Eckner et al (2014).

By adopting the guidelines outlined by the above articles, the potential risk for injury should be reduced. The studies outlined that no injuries were sustained during testing.

Additionally:

- Alricsson et al (2004) comment that isometric neck strength testing (with the load cell equipment in tension), as suggested for this study, was performed regularly when testing the neck strength of Swedish Air Force pilots.
- Ylinen et al (2006) used tension load cell equipment isometric neck strength exercises for 1 year to rehabilitate individuals with chronic neck pain – resulting in increased neck strength and a significant decrease in neck pain

Answer c)

- No invasive procedures are involved in this study

Answer d)

- No sensitive data will be collected in this study

Answer e)

- If the participant were to experience discomfort during the testing procedure, the session would immediately stop.
- If the discomfort was pain from an injury sustained during testing, then first aid would be provided immediately (hospital treatment may be recommended depending on the severity of the injury).

Answer f)

- Feedback for the individual:

A report will be provided for every test volunteer. This will provide personal test scores and highlight asymmetries located in the neck region. This will be compared against average test scores within their weight category.

- Long term benefits of the study:

Primary Study (neck strength of boxers): Results are to be examined to understand:

- General neck strength symmetry patterns (left versus right side and forward verses backwards).
- Neck strength patterns between boxing weight categories.
- Boxing neck strength comparisons with other sports
- This will also provide base line neck strength statistics for strength and conditioning coaches working within boxing. This may help to correctly develop neck strength of boxers, allowing them to better absorb punch forces.

Secondary Findings (Reliability study): Stable and consistent data within this part of the study should provide confidence in the reliability of the primary study results.

21. Confidentiality, privacy and data protection

a) What steps will be taken to ensure participants' confidentiality?

- Please describe how data, particularly personal information, will be stored (all electronic data must be stored on St Mary's University servers).
- Consider how you will identify participants who request their data be withdrawn, such that you can still maintain the confidentiality of theirs and others' data.

b) Describe how you will manage data using a data a management plan.

- You should show how you plan to store the data securely and select the data that will be made publically available once the project has ended.

- You should also show how you will take account of the relevant legislation including that relating data protection, freedom of information and intellectual property.

c) Who will have access to the data? Please identify all persons who will have access to the data (normally yourself and your supervisor).

d) Will the data results include information which may identify people or places?

- Explain what information will be identifiable.
- Whether the persons or places (e.g. organisations) are aware of this.
- Consent forms should state what information will be identifiable and any likely outputs which will use the information e.g. dissertations, theses and any future publications/presentations.

Confidentiality & Data Storage:

- Two hard copy folders will be established, entitled: 'Participation' and 'Withdrawn.'
- Hard copy files for each participant will be set up in the 'Participation' folder. Any data collected (as described in the 'collected information' section) on an individual will be stored within this file.
- If a participant wishes to withdraw from the study, their file will be transferred from the 'Participation' folder into the 'Withdrawn' folder.
- Both folders will be stored in a lockable filing cabinet.

Transfer to Electronic Storage:
Each participant wishing to remain in the study, will be given a participant number (recorded on their hard copy file).

The following information will then be transferred on to an electronic database (stored on SMU server) entitled 'Data Logging':

- Participant number
- Body mass
- Boxing weight category
- Neck strength measurements

No names of any participants will be entered electronically. This should ensure anonymity for the individuals throughout the data calculation process.

Individuals who withdraw after the data is logged electronically will have their data information deleted from all electronic files.

Participants can request a copy of their test results. However, they will not be allowed to request the results of other participants.

A Data Management Plan is attached at the end of this application form

Data Access is only granted to:
Kevin Gallagher (Research coordinator) email: 125555@live.stmarys.ac.uk
Dr. Daniel Cleather (Study supervisor) email: daniel.cleather@stmarys.ac.uk

Anonymity of Published Data/ Results:
The results will not identify individuals. The consent form refers potential participants to the Research Project Participant Information Sheet. The Information sheet clearly states what data is collected, and how the collected data is to be collected, correlated, and presented.

All electronic data will be stored on St. Mary's University servers.

22. Feedback to participants
Please give details of how feedback will be given to participants: • As a minimum, it would normally be expected for feedback to be offered to participants in an acceptable to format, e.g. a summary of findings appropriately written. • Please state whether you intend to provide feedback to any other individual(s) or organisation(s) and what form this would take.
If requested by an individual, a report can be forwarded. This will provide personal test scores and highlight asymmetries located in the neck region. This will be compared against average test scores within their weight category. All participants will be offered the opportunity for the research coordinator to present the project's findings to their club. This will only be done after the dissertation process has been completed and a mark for the project given. This will be free of charge.

The proposer recognises their responsibility in carrying out the project in accordance with the University's Ethical Guidelines and will ensure that any person(s) assisting in the research/ teaching are also bound by these. The Ethics Sub-Committee must be notified of, and approve, any deviation from the information provided on this form.

Signature of Proposer(s)	Date: 30/11/16
Signature of Supervisor (for student research projects)	Date: 05/12/16

A.2. Ethics Approval Referral

St Mary's University Twickenham London

Approval Sheet

Name of applicant: Kevin Gallagher

Name of supervisor: Dr. Daniel Cleather

Programme of study: MSc Strength and Conditioning

Title of project: "Isometric Neck Strength Symmetry and Correlation with Body Mass of Male Amateur Boxers"

Supervisors, please complete section 1 or 2. If approved at level 1, please forward a copy of this Approval Sheet to the School Ethics Representative for their records.

SECTION 1

Approved at Level 1

Signature of supervisor (for student applications)..

Date..

SECTION 2

Refer to School Ethics Representative for consideration at Level 2 or Level 3

Signature of supervisor..
....

Date....05/12/16..

SECTION 3

To be completed by School Ethics Representative

Approved at Level 2

Signature of School Ethics Representative..

Date..

SECTION 4

To be completed by School Ethics Representative. Level 3 consideration required byt the Ethics Sub-Committee (including all staff research involving human participants)

Signature of School Ethics Representative..

Date..

Level 3 approval – confirmation will be via correspondence from the Ethics Sub-Committee

A.3. Ethics Approval Confirmation

St Mary's
University
Twickenham
London

5 January 2017

Unique Ref: SMEC_2016-17_046

Kevin Gallagher (SHAS): 'Isometric Neck Strength Symmetry and Correlation with Body Mass of Male Amateur Boxers'.

Dear Kevin

University Ethics Sub-Committee

Thank you for submitting your ethics application for the above research.

I can confirm that your application has been considered by the Ethics Sub-Committee and that ethical approval is granted.

Yours sincerely

Prof Conor Gissane
Chair of the Ethics Sub-Committee

Cc Dr Daniel Cleather

Appendix B – Participant Recruitment

B.1. Participant Invitation Letter

St Mary's University Twickenham London

My name is Kevin Gallagher. I am studying for a master's degree in strength and conditioning at St. Mary's University, Twickenham. I am undertaking a research project as part of my final year, which is entitled:

'Isometric Neck Strength Symmetry and Correlation with Body Mass of Senior Male Amateur Boxers.'

The primary focus of the study is the collection of neck strength data of amateur boxers for comparison within and between the various fighting weight categories body mass and boxing experience. A secondary focus is to investigate the reliability of this neck strength test.

I am inviting members of your boxing club to participate in this project. Details of the research are provided on the information sheet enclosed.

If you have questions regarding this research, please do not hesitate to contact me on the email address provided.

Regards,

Kevin Gallagher (Research coordinator)
Email: 125555@live.stmarys.ac.uk

(Project supervisor: Dr. Daniel Cleather, St Mary's University, Waldegrave Rd, Twickenham. TW1 4SX.
Email: daniel.cleather@stmarys.ac.uk)

B.2. Participant Information Sheet

St Mary's University Twickenham London

MSc Study Research Project Participant Information & Formal Invitation Sheet

Section A: The Research Project

Title: "Isometric Neck Strength Symmetry and Correlation with Body Mass of Male Amateur Boxers."

Background:
Information relating to a boxer's ability to absorb a punch is under investigated. Research in other contact sports have focused on neck strength as being critical to absorbing forces to the head.

Studies Purpose:
This study will collect neck strength data across all the weight divisions of senior male amateur boxing for comparison.

Results:

- All data will be presented as a group finding and not as individual results. This will allow assessment on:
    - General neck strength symmetry patterns (left versus right side etc.) within the sport.
    - Neck strength patterns within and between weight categories.
    - Compare the neck strength of boxers against data from other sports.
    - This will also provide baseline neck strength statistics for strength and conditioning coaches working within boxing.

Secondary Findings: Reliability study to provide confidence in the testing procedure and results of the primary study.

Reporting of Results: The results of the study will be presented:

- In a report as part of the author's master's degree.
- In a research journal or presented at a conference or workshop.
- Online through social media.
- A free presentation of the report's findings will be offered to any club or organisation that provides participants to the study.

Confidentiality:
Your agreement to participate in this study will be strictly confidential. All documentation will be:

- Submitted for archive filing at the university.
- Your personal or sensitive data will only be viewed by parties involved in the research project.
- Your personal or sensitive data will not be accessible for general viewing or presented as part of any public published report. Therefore, your anonymity will be protected.

- You have the right to view your own data and measured test results. You will not be granted access to any other individual's data.

Section B: Agreeing to Participate in the Research Project

If you agree to participate in the study, you will be asked to:

- Complete a medical history PAR-Q (physical activity readiness questionnaire) form.
    - Please answer truthfully
    - Please note that answers given may prevent you from taking part in the study.
- Perform a supervised warm-up to the neck and shoulders region.
- Be seated on a bench & strapped at the waist and chest. This will secure you to two upright posts.
- A head harness will be placed around your head.
    - This will be secured with a strap around the chin and around the girth of your head.
- The head harness will be attached to the testing equipment.
- Activate your neck muscles to resist a force that is applied to the head and hold it for 5 seconds, in 4 specified directions.
    - Forward & back
    - Tilt left and right
- Each direction will be tested 3 times

The whole test duration will not last longer than 25 minutes.

Injury Risk:
Any resistance test has an injury risk. However, the risks of taking part in the study are no greater than they would be if taking part in a normal neck strengthening training session. To minimise this risk, the testing procedure will follow the following good practice:

- Completed risk assessment.
- Medical history questionnaire for participants.
- Ensure the you fully understand the testing procedure (This will include a practice if required).
- Thorough warm-up to the neck & shoulders.
- Correct head positioning during test
- Correct muscle contraction during test
- Appropriate rest between contraction attempts.
- Correct use of the testing equipment as outlined by the manufacturers.
- Supervised testing
- First aider will be present

The proposed methods of testing have been approved via the St. Mary's University Ethics Application process. For a copy of the universities ethics guidelines please email the research coordinator at the email address provided in Section F.

Section C: Legal Rights

Please note that agreement to participate in this research will not affect your legal rights if something goes wrong.

Participation in this study is voluntary. No participants will be paid for this research.

All data is collected and processed in accordance with the Data Protection Act (1998) which allows the Reacher to:

- Collect data for a specific and lawful purpose.

- Collect data relative to the study that is not necessarily imposing or excessive.
- Collect data that is adequate and current.
- Ensure that data is not be kept longer than necessary.
- Ensure that data is fairly and lawfully processed.
- Ensure that data is kept secure and not transferred unnecessarily or without adequate protection.

Section D: Formal Invitation

Your head coach suggested that you matched the following criteria to be a volunteer in this study:

- Male
- Over 18 years' old
- Competitive amateur boxer
- Available for testing between 9/1/17 and 22/1/17

Testing Address:
Eglington Boxing Club, Unit 21, Vale Centre, Greysteel, Co. Derry BT47 3GE.

If you wish to freely participate in this study, please:

- Ask your head coach for a consent form.
- Complete and return the form to your head coach for collection by the research coordinator.
- A copy of your consent form will be given to you for your records.

Please note that you are under no obligation from any party to take part in the study.

Section E: Study Withdrawal

You will have the right to withdraw from the study at any time without reason.

If to wish to withdraw please:

- Complete the withdrawal section on your consent form.
- Hand this form to your head coach. (It will be collected the research coordinator on test day).
- Your head coach will email the research coordinator about your withdrawal from the study.

Please note, due to the test-day coordination, it would be helpful if a minimum 48 hours' notice is provided.

Section F: Further Information

For further information please contact the research coordinator:

Research Coordinator	Study Supervisor
Kevin Gallagher St Mary's University, Waldegrave Rd, Twickenham. TW1 4SX Email: 125555@live.stmarys.ac.uk	Dr. Daniel Cleather St Mary's University, Waldegrave Rd, Twickenham. TW1 4SX Email: daniel.cleather@stmarys.ac.uk

There is no external funding from any organisation for this research.

B.3. Participant Consent Form

St Mary's University Twickenham London

Participant Consent Form

Name of Participant: ____

Title of the project: Isometric Neck Strength Symmetry and Correlation with Body Mass of Senior Male Amateur Boxers.

Research coordinator's contact details:
Kevin Gallagher, St Mary's University, Waldegrave Rd, Twickenham. TW1 4SX
Email: **125555@live.stmarys.ac.uk**

Other members of the research team:
The Study is Supervised by:
Dr. Daniel Cleather St Mary's University, Waldegrave Rd, Twickenham. TW1 4SX
Email: daniel.cleather@stmarys.ac.uk

1. I agree to take part in the above research. I have read the Participant Information Sheet which is attached to this form. I understand what my role will be in this research, and all my questions have been answered to my satisfaction.
2. I understand that I am free to withdraw from the research at any time, for any reason and without prejudice.
3. I have read the Data Management Plan for this project which outlines data collection and how the confidentiality of the information collected will be safeguarded.
4. I am free to ask any questions at any time before and during the study.
5. I have been provided with a copy of this form, the Participant Information Sheet & the Data Management Plan

Data Protection: I agree to the University processing personal data which I have supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.

Name of participant (print)……………………………………………………………

Signed………………………… Date………………………

If you wish to withdraw from the research, please complete the form below and return to the main investigator named above.

Title of Project: ____

I WISH TO WITHDRAW FROM THIS STUDY

Name: ____

Signed: ____________________________ Date: ____________________

Appendix C – Information and Data Collection

C.1. Physical Activity Readiness Questionnaire (PAR-Q) Form

St Mary's University Twickenham London

SCHOOL OF Sport, health and applied science

CONFIDENTIAL Medical History / Physical Activity Readiness Questionnaire (PAR-Q) FORM

This screening form must be used in conjunction with an agreed Consent Form.

Full Name:		Date of Birth:	
Height (cm):		Weight (kg):	

Emergency Contact Telephone Number ………………………………………………

Emergency Contact Name ………………………………………………

Have you ever suffered from any of the following medical conditions? If yes please give details:

	Yes	No	Details
Heart Disease or attack	☐	☐	………………………………………
High or low blood pressure	☐	☐	………………………………………
Stroke	☐	☐	………………………………………
Cancer	☐	☐	………………………………………
Diabetes	☐	☐	………………………………………
Asthma	☐	☐	………………………………………
High cholesterol	☐	☐	………………………………………
Epilepsy	☐	☐	………………………………………
Allergies	☐	☐	………………………………………
Other, please give details	☐	☐	………………………………………

……………………………………………………………………………………………………

Do you or have your family suffered from any form of deep vein thrombosis / blood clots.
If yes please give details;

Please give details of any medication you are currently taking or have taken regularly within the last year:

Please give details of any musculoskeletal / orthopaedic injuries you have had in the past 12 months which have affected your capacity to exercise or caused you to take time off work or seek medical advice:

Other Important Information

During a typical week approximately how many hours would you spend exercising?

If you smoke please indicate how many per day:

If you drink alcohol please indicate how many units per week:

Are you currently taking any supplements or medication? Please give details:

Is there any reason not prompted above that would prevent you from participating within the relevant activity?

Are you aware of any reasons why you may not be able to where a head harness (e.g. Head lice, cuts or sores to the scalp, skin irritations etc.)

Due to the nature of the study, individuals who have a history of neck pain / injury will be excluded.

Have you ever had a neck injury, or are you currently suffering from neck pain?

Yes ☐ No ☐ Details...

By signing this document, I agree to inform the relevant individual(s) of any change(s) to my circumstances that would prevent me from participating in specific activities.

Signature (Participant): Date:

Signature (Test Coordinator*): Date:

*Test coordinator: The individual responsible for administering the test(s)/session

C.2. Test Data Collection Sheet

St Mary's University
Twickenham
London

Data Logging Sheet

Participants Name:	
Participant Number	
Boxing Experience (years)	
Weight Category	
Fighting Stance (Orthodox / Southpaw)	

Isometric Neck Strength Recorded Test Data (N)

	Attempt		
	1	2	3
Neck Flexion			
Neck Extension			
Left Lateral Flexion			
Right Lateral Flexion			

Appendix D. Tabulated Data

D.1.Test 1 and Test 2 Reliability Study Data

TABLE 3. Reliability Study Data of 10 Participants: Test 1. Age (yrs) height (m) and body mass (kg) data was recorded with three maximal isometric neck strength attempts in flexion (F1, F2, F3), extension (E1, E2, E3), left lateral flexion (LLF1, LLF2, LLF3) and right lateral flexion (RLF1, RLF2, RLF3). Maximum score from each neck strength test direction was recorded (Fmax, Emax, Lmax, Rmax) for flexion, extension, left and right lateral flexion respectively. Mean score of the three attempts from each direction was calculated (Fmean, Emean, Lmean and Rmean).

PartNo	Age	Ht	Bmass	F1	F2	F3	Fmax	Fmean	E1	E2	E3	Emax	Emean	LLF1	LLF2	LLF3	Lmax	Lmean	RLF1	RLF2	RLF3	Rmax	Rmean
1	37.4	180.0	81.2	144.2	137.9	151.2	151.2	144.4	197.6	180.5	197.3	197.6	191.8	193.2	203.6	205.3	205.3	200.7	185.6	186.8	182.1	186.8	184.8
2	19.1	183.0	85.7	305.4	292.0	302.1	305.4	299.8	260.7	262.9	270.1	270.1	264.6	279.7	268.2	272.4	279.7	273.4	295.3	282.9	288.4	295.3	288.9
3	43.2	185.0	115.2	130.7	145.0	130.9	145.0	135.5	199.9	199.6	205.4	205.4	201.6	198.2	190.5	198.7	198.7	195.8	205.9	200.8	197.4	205.9	201.4
4	33.3	183.0	101.0	107.2	103.6	101.4	107.2	104.1	155.3	154.9	141.6	155.3	150.6	140.1	152.9	157.6	157.6	150.2	157.4	162.3	155.7	162.3	158.5
5	27.4	178.0	94.6	160.2	168.9	162.7	168.9	163.9	200.7	195.2	196.2	200.7	197.4	194.2	197.0	183.2	197.0	191.5	192.2	208.1	196.2	208.1	198.8
6	42.5	179.0	74.0	130.7	118.9	113.2	130.7	120.9	144.9	158.2	144.7	158.2	149.3	170.8	169.0	162.6	170.8	167.5	161.3	171.5	177.5	177.5	170.1
7	32.5	177.0	86.0	203.2	185.9	203.2	203.2	197.4	297.6	287.4	299.7	299.7	294.9	280.6	279.5	284.6	284.6	281.6	291.7	289.1	299.3	299.3	293.4
8	43.4	176.0	71.4	149.8	160.3	161.1	161.1	157.1	241.8	235.3	232.1	241.8	236.4	163.1	179.3	177.4	179.3	173.3	184.7	188.2	185.1	188.2	186.0
9	35.4	182.0	96.1	110.3	107.2	102.2	110.3	106.6	152.1	142.3	156.2	156.2	150.2	113.7	108.2	109.9	113.7	110.6	102.0	97.8	100.5	102.0	100.1
10	27.4	178.0	79.7	106.3	110.2	107.8	110.2	108.1	133.9	135.2	131.1	135.2	133.4	130.7	127.1	122.6	130.7	126.8	137.6	137.6	143.2	143.2	139.5

TABLE 4. Reliability Study Data of 10 Participants: Test 2. Age (yrs) height (m) and body mass (kg) data was recorded with three maximal isometric neck strength attempts in flexion (F1, F2, F3), extension (E1, E2, E3), left lateral flexion (LLF1, LLF2, LLF3) and right lateral flexion (RLF1, RLF2, RLF3). Maximum score from each neck strength test direction was recorded (Fmax, Emax, Lmax, Rmax) for flexion, extension, left and right lateral flexion respectively. Mean score of the three attempts from each direction was calculated (Fmean, Emean, Lmean and Rmean).

PartNo	Age	Ht	Bmass	F1	F2	F3	Fmax	Fmean	E1	E2	E3	Emax	Emean	LLF1	LLF2	LLF3	Lmax	Lmean	RLF1	RLF2	RLF3	Rmax	Rmean
1	37.4	180.0	81.2	148.6	144.7	147.2	148.6	146.8	171.9	175.7	178.1	178.1	175.2	194.7	200.9	193.6	200.9	196.4	188.3	172.9	184.3	188.3	181.8
2	19.1	183.0	85.7	309.1	308.7	295.4	309.1	304.4	369.1	369.7	377.4	377.4	372.1	276.4	255.8	272.4	276.4	268.2	289.1	287.3	279.3	289.1	285.2
3	43.2	185.0	115.2	132.7	136.9	132.1	136.9	133.9	287.3	293.6	284.2	293.6	288.4	199.6	202.5	204.3	204.3	202.1	199.6	200.0	220.0	220.0	206.5
4	33.3	183.0	101.0	102.5	93.7	99.9	102.5	98.7	148.8	156.5	154.7	156.5	153.3	147.0	138.7	143.2	147.0	143.0	153.3	150.9	148.6	153.3	150.9
5	27.4	178.0	94.6	184.2	200.1	188.3	200.1	190.9	205.2	199.7	202.8	205.2	202.6	195.6	181.9	197.4	197.4	191.6	206.7	199.3	209.3	209.3	205.1
6	42.5	179.0	74.0	123.7	130.8	135.0	135.0	129.8	146.7	138.9	143.2	146.7	142.9	177.9	164.4	165.2	177.9	169.2	174.1	168.9	166.2	174.1	169.7
7	32.5	177.0	86.0	175.6	192.6	188.5	192.6	185.6	323.2	302.6	305.3	323.2	310.4	308.6	309.2	297.3	309.2	305.0	305.7	311.7	319.2	319.2	312.2
8	43.4	176.0	71.4	174.9	174.9	166.3	174.9	172.0	243.6	249.7	239.3	249.7	244.2	154.0	163.1	165.7	165.7	160.9	187.6	180.1	191.6	191.6	186.4
9	35.4	182.0	96.1	100.3	98.6	97.9	100.3	98.9	152.1	157.9	147.1	157.9	152.4	121.0	118.1	122.1	122.1	120.4	112.2	103.6	105.7	112.2	107.2
10	27.4	178.0	79.7	115.7	109.3	115.2	115.7	113.4	137.7	133.6	134.2	137.7	135.2	138.4	129.9	141.2	141.2	136.5	141.2	147.6	137.9	147.6	142.2

D.2. Normative Study Data

TABLE 5. Normative Study Data of 102 Participants (Nos. 1 to 53): Age (yrs) height (m), body mass (kg), training experience (yrs), categorised fighting stance and categorised fighting weight d data are recorded. Three maximal isometric neck strength attempts in flexion (F1, F2, F3), extension (E1, E2, E3), left lateral flexion (LLF1, LLF2, LLF3) and right lateral flexion (RLF1, RLF2, RLF3) provided information to calculate mean absolute scores (N) (FmeanAb, EmeanAb, LmeanAb, RmeanAb) and allometric scaled (N/kg$^{0.67}$) (FmeanAl, EmeanAl, LmeanAl, RmeanAl) for flexion, extension, left and right lateral flexion respectively.

PartNo	Age	Ht	Bmass	TrainExp	WtDiv	Stance	F1	F2	F3	FMeanAb	FMeanAl	E1	E2	E3	EMeanAb	EMeanAl	LLF1	LLF2	LLF3	LMeanAb	LMeanAl	RLF1	RLF2	RLF3	RMeanAb	RMeanAl
1	20.9	183.0	91.7	4	10	1	265.9	252.6	240.8	253.1	12.3	281.3	292.4	292.8	288.8	14.0	238.3	234.6	248.6	240.5	11.7	271.8	274.8	273.2	273.3	13.2
2	26.9	182.0	76.5	12	7	2	252.6	247.8	249.5	250.0	13.7	268.3	269.7	250.2	262.7	14.4	287.9	292.6	301.6	294.0	16.1	310.2	307.2	310.7	309.4	16.9
3	18.7	176.0	66.8	3	6	2	275.4	293.6	289.7	286.2	17.1	320.6	313.9	313.2	315.9	18.9	284.2	273.6	268.7	275.5	16.5	252.6	261.3	267.6	260.5	15.6
4	18.4	177.0	58.2	1	4	1	234.7	220.9	226.7	227.4	14.9	259.6	240.1	251.3	250.3	16.4	230.2	234.6	230.6	231.8	15.2	250.9	254.3	256.3	253.8	16.7
5	22.2	187.0	75.7	2	8	1	338.6	356.6	355.2	350.1	19.3	311.2	318.2	313.6	314.3	17.3	307.6	299.2	307.7	304.8	16.8	320.6	327.1	318.4	322.0	17.7
6	19.2	172.0	58.1	1	5	1	300.1	294.7	297.8	297.5	19.6	223.6	239.6	244.0	235.7	15.5	263.9	267.3	259.6	263.6	17.3	251.6	251.7	244.8	249.4	16.4
7	18.6	180.0	78.0	11	7	2	221.8	220.4	218.6	220.3	11.9	223.2	225.9	230.6	226.6	12.2	204.6	208.6	201.4	204.9	11.1	240.3	228.6	233.5	234.1	12.6
8	20.1	175.0	73.3	10	6	1	260.1	260.2	251.6	257.3	14.5	299.4	290.6	301.7	297.2	16.7	266.1	261.5	271.3	266.3	15.0	266.4	253.7	249.9	256.7	14.4
9	38.9	197.0	123.1	20	10	1	381.9	374.9	361.7	372.8	14.8	337.6	355.1	356.7	349.8	13.9	330.6	326.6	334.4	330.5	13.1	310.7	319.0	320.2	316.6	12.6
10	18.5	178.0	62.9	5	5	2	192.7	180.3	187.0	186.7	11.6	221.7	207.9	213.6	214.4	13.4	174.6	180.2	188.3	181.0	11.3	205.6	199.2	219.3	208.0	13.0
11	21.4	172.0	60.1	5	4	1	233.6	248.7	252.6	245.0	15.8	213.2	214.6	217.6	215.1	13.8	160.3	170.2	190.3	173.6	11.2	193.2	199.6	197.6	196.8	12.7
12	18.2	187.0	73.5	5	7	1	151.7	169.8	155.7	159.1	8.9	180.2	176.3	171.2	175.9	9.9	166.7	178.2	166.2	170.4	9.6	140.8	141.2	147.0	143.0	8.0
13	33.0	172.0	78.7	5	8	1	219.7	237.8	240.2	232.6	12.5	192.6	227.9	232.4	217.6	11.7	191.6	192.6	201.6	195.3	10.5	215.2	223.7	226.6	221.8	11.9
14	37.7	172.0	75.4	9	7	1	289.7	287.6	302.9	293.4	16.2	369.7	388.2	399.0	385.6	21.3	287.9	273.4	289.6	283.6	15.7	262.3	268.3	250.1	260.2	14.4
15	18.3	187.0	78.4	3	7	1	282.9	268.7	259.5	270.4	14.5	349.2	348.7	353.7	350.5	18.9	252.7	250.9	248.2	250.6	13.5	245.0	247.2	252.9	248.4	13.4
16	18.6	172.0	68.4	10	6	1	239.7	232.6	236.3	236.2	13.9	252.7	252.7	256.9	254.1	15.0	171.9	191.7	189.7	184.4	10.9	208.3	213.9	209.7	210.6	12.4
17	19.5	183.0	80.1	4	7	2	130.6	123.9	139.6	131.4	7.0	169.8	173.6	170.8	171.4	9.1	150.3	155.6	141.7	149.2	7.9	144.9	132.7	149.1	142.2	7.5
18	18.8	170.0	74.9	1	7	1	204.1	220.6	211.6	212.1	11.8	370.8	371.9	365.2	369.3	20.5	188.7	221.6	219.0	209.8	11.6	199.6	190.6	205.4	198.5	11.0
19	19.4	178.0	68.4	2	7	1	139.7	155.2	153.7	149.5	8.8	168.3	172.8	189.3	176.8	10.4	183.7	176.9	184.7	181.8	10.7	131.8	140.9	127.8	133.5	7.9
20	27.0	176.0	69.4	8	5	1	187.6	208.3	199.3	198.4	11.6	221.6	221.7	214.6	219.3	12.8	230.6	243.6	250.2	241.5	14.1	248.6	236.7	244.1	243.1	14.2
21	18.2	201.0	95.3	1	10	1	120.9	123.7	115.8	120.1	5.7	123.1	135.8	128.6	129.2	6.1	154.6	167.2	169.3	163.7	7.7	108.2	108.2	118.7	111.7	5.3
22	25.4	173.0	60.8	5	4	1	135.6	121.5	120.5	125.9	8.0	160.9	164.7	162.8	162.8	10.4	148.2	158.9	147.0	151.4	9.7	130.2	134.6	144.7	136.5	8.7
23	19.9	177.0	55.7	5	3	1	177.3	182.1	170.1	176.5	11.9	192.6	188.3	194.4	191.8	13.0	160.2	149.8	157.6	155.9	10.5	155.4	151.0	152.9	153.1	10.4
24	18.6	181.0	67.9	4	6	2	175.3	154.2	154.7	161.4	9.6	196.6	211.6	210.4	206.2	12.2	162.1	152.9	165.7	160.2	9.5	180.3	191.6	184.2	185.4	11.0
25	22.9	169.0	60.2	5	4	1	260.7	259.6	233.5	251.3	16.1	223.1	230.4	220.7	224.7	14.4	224.6	226.3	220.1	223.7	14.4	201.2	210.6	208.7	206.8	13.3
26	18.2	176.0	64.2	7	6	1	69.2	60.7	64.9	64.9	4.0	102.3	123.6	128.6	118.2	7.3	184.6	179.2	177.3	180.4	11.1	160.9	175.4	173.3	169.9	10.5
27	24.7	183.0	80.1	10	9	1	247.3	235.6	233.0	238.6	12.7	293.9	280.6	293.7	289.4	15.3	277.4	303.4	299.6	293.5	15.6	292.3	305.8	310.2	302.8	16.1
28	30.6	186.0	97.5	3	10	2	182.0	211.6	20.6	138.1	6.4	262.7	224.6	231.2	239.5	11.1	161.3	169.7	172.6	167.9	7.8	171.2	177.9	185.7	178.3	8.3
29	26.5	164.0	50.8	6	2	1	245.5	225.9	226.4	232.6	16.7	247.3	248.8	251.6	249.2	17.9	245.6	231.9	236.7	238.1	17.1	230.7	233.0	229.6	231.1	16.6
30	20.0	173.0	64.0	13	5	1	278.6	276.3	260.9	271.9	16.8	329.7	328.6	333.2	330.5	20.4	352.4	328.9	347.2	342.8	21.1	232.9	240.6	234.7	236.1	14.6
31	19.7	197.0	91.4	1	10	1	187.2	165.2	188.7	180.4	8.8	243.9	244.3	257.8	248.7	12.1	225.7	223.6	210.7	220.0	10.7	167.3	155.1	164.3	162.2	7.9
32	25.5	175.0	64.7	7	5	1	140.3	140.2	148.2	142.9	8.7	125.3	122.6	138.1	128.7	7.9	109.7	108.6	118.2	112.2	6.9	153.2	162.1	159.7	158.3	9.7
33	25.5	197.0	107.4	2	10	1	234.4	211.3	227.9	224.5	9.8	255.1	260.6	257.3	257.7	11.2	242.9	232.7	240.6	238.7	10.4	217.6	222.9	221.4	220.6	9.6
34	18.7	181.0	62.6	5	4	1	212.7	189.7	207.6	203.3	12.7	238.9	260.2	238.0	245.7	15.4	206.9	199.0	187.2	197.7	12.4	202.6	220.6	221.4	214.9	13.4
35	20.1	170.0	54.8	3	3	1	181.7	199.3	195.1	192.0	13.1	210.7	220.1	217.6	216.1	14.8	217.7	198.5	218.2	211.5	14.5	196.2	203.6	193.1	197.6	13.5
36	19.0	171.0	57.0	8	3	1	265.4	291.6	292.0	283.0	18.9	308.9	337.2	301.6	315.9	21.0	332.1	324.7	339.7	332.2	22.1	307.2	322.9	301.8	310.6	20.7
37	18.1	171.0	56.1	11	3	1	188.2	201.3	209.3	199.6	13.4	207.1	192.3	207.2	202.2	13.6	233.7	237.5	230.4	233.9	15.7	207.3	209.6	209.6	208.8	14.1
38	20.0	175.0	83.3	1	9	2	198.1	172.3	175.3	181.9	9.4	126.2	122.0	153.7	134.0	6.9	160.2	158.7	142.3	153.7	7.9	201.7	194.6	204.6	200.3	10.3
39	25.3	176.0	80.0	3	8	1	208.7	208.1	189.2	202.0	10.7	195.7	194.2	198.2	196.0	10.4	220.2	234.7	250.2	235.0	12.5	242.3	257.6	236.1	245.3	13.0
40	19.2	178.0	68.5	2	6	1	120.9	123.7	119.6	121.4	7.1	161.7	180.2	177.0	173.0	10.2	140.2	145.7	148.2	144.7	8.5	118.2	157.6	160.2	145.3	8.6
41	19.3	182.0	81.2	4	9	1	228.4	209.6	223.7	220.6	11.6	288.2	300.2	318.2	302.2	15.9	240.3	285.6	285.4	270.4	14.2	242.6	247.6	244.7	245.0	12.9
42	18.4	187.0	58.1	2	5	2	190.2	189.6	189.3	189.7	12.5	188.7	203.6	200.8	197.7	13.0	184.6	157.2	160.2	167.3	11.0	194.7	206.1	205.1	202.0	13.3
43	19.0	175.0	58.8	1	4	1	162.3	165.2	152.0	159.8	10.4	149.2	150.8	149.6	149.9	9.8	158.2	161.7	158.3	159.4	10.4	175.1	164.8	156.5	165.5	10.8
44	22.0	178.0	59.9	2	5	1	213.1	196.7	193.5	201.1	13.0	219.7	208.0	215.2	214.3	13.8	207.8	209.6	206.9	208.1	13.4	204.4	208.1	204.1	205.5	13.2
45	19.1	178.0	80.7	4	8	2	268.2	253.1	243.7	255.0	13.5	295.4	305.6	300.4	300.5	15.9	270.1	285.7	290.4	282.1	14.9	301.7	298.1	313.8	304.5	16.1
46	18.1	175.0	69.0	12	7	1	220.4	230.2	204.6	218.4	12.8	249.6	279.3	289.6	272.8	16.0	232.6	241.7	236.0	236.8	13.9	230.4	230.2	241.8	234.1	13.7
47	18.6	180.0	71.6	6	6	1	220.4	200.1	198.7	206.4	11.8	340.7	320.6	331.4	330.9	18.9	257.6	258.6	275.3	263.8	15.1	240.1	250.7	260.3	250.4	14.3
48	19.0	157.0	49.1	6	2	1	255.7	241.2	236.6	244.5	18.0	240.1	255.6	251.8	249.2	18.3	220.1	237.1	234.0	230.4	17.0	228.7	230.9	242.7	234.1	17.2
49	20.7	188.0	87.2	5	9	1	244.2	247.6	269.7	253.8	12.7	235.7	242.9	267.3	248.6	12.5	307.2	297.6	308.1	304.3	15.2	294.7	298.1	298.3	297.0	14.9
50	38.1	181.0	75.0	12	7	1	196.2	196.2	195.7	196.0	10.9	295.4	267.8	279.6	280.9	15.6	218.6	230.5	245.7	231.6	12.8	231.6	250.1	251.6	244.4	13.5
51	18.8	174.0	56.2	9	4	2	217.6	210.8	196.2	208.2	14.0	242.9	223.7	230.6	232.4	15.6	165.7	187.2	188.3	180.4	12.1	221.4	206.5	220.0	216.0	14.5
52	19.2	181.0	63.1	7	6	1	183.9	184.1	178.8	182.3	11.3	280.2	288.4	277.7	282.1	17.6	231.6	245.7	246.9	241.4	15.0	223.7	233.2	255.5	237.5	14.8
53	22.9	200.0	85.0	3	9	1	198.1	203.5	205.1	202.2	10.3	281.7	270.7	274.7	275.7	14.1	256.5	252.7	244.6	251.3	12.8	242.0	215.3	250.4	235.9	12.0

TABLE 6. Normative Study Data of 102 Participants (Nos. 54 to 102): Age (yrs) height (m), body mass (kg), training experience (yrs), categorised fighting stance and categorised fighting weight division (see table X) data are recorded. Three maximal isometric neck strength attempts in flexion (F1, F2, F3), extension (E1, E2, E3), left lateral flexion (LLF1, LLF2, LLF3) and right lateral flexion (RLF1, RLF2, RLF3) provided information to calculate mean absolute scores (N) (FmeanAb, EmeanAb, LmeanAb, RmeanAb) and allometric scaled (N/kg$^{0.67}$) (FmeanAl, EmeanAl, LmeanAl, RmeanAl) for flexion, extension, left and right lateral flexion respectively.

PartNo	Age	Ht	Bmass	TrainExp	WtDiv	Stance	F1	F2	F3	FMeanAb	FMeanAl	E1	E2	E3	EMeanAb	EMeanAl	LLF1	LLF2	LLF3	LMeanAb	LMeanAl	RLF1	RLF2	RLF3	RMeanAb	RMeanAl
54	34.9	179.0	75.3	14	8	1	233.9	220.4	217.1	223.8	12.4	184.6	172.6	181.2	179.5	9.9	182.6	201.6	196.4	193.5	10.7	181.7	184.6	192.6	186.3	10.3
55	18.6	183.0	77.5	8	7	1	318.2	316.1	319.7	318.0	17.2	350.2	343.9	359.6	351.2	19.0	301.2	282.6	283.7	289.2	15.7	275.3	295.4	286.5	285.7	15.5
56	26.6	179.0	71.2	10	7	1	184.7	189.6	191.1	188.5	10.8	226.3	208.5	215.9	216.9	12.4	227.6	228.5	225.7	227.3	13.0	201.7	217.3	220.6	213.2	12.2
57	18.6	176.0	52.9	4	3	1	155.2	158.9	148.1	154.1	10.8	215.9	214.2	223.8	218.0	15.3	219.7	235.2	210.2	221.7	15.5	190.7	205.3	205.0	200.3	14.0
58	21.3	166.0	56.0	4	3	1	157.2	165.8	156.2	159.7	10.8	169.2	168.3	161.0	166.2	11.2	142.7	140.2	153.2	145.4	9.8	120.2	129.3	126.2	125.2	8.4
59	25.1	184.0	64.6	14	6	2	140.2	132.3	138.7	137.1	8.4	234.7	215.7	242.6	231.0	14.1	135.2	148.2	148.9	144.1	8.8	174.9	157.0	168.3	166.7	10.2
60	27.8	184.0	80.9	9	8	1	238.2	240.7	243.1	240.7	12.7	251.0	246.8	248.4	248.7	13.1	236.6	228.8	241.5	235.6	12.4	221.6	227.8	217.1	222.2	11.7
61	18.3	182.0	66.4	7	5	1	165.2	173.8	178.9	172.6	10.4	178.9	190.2	203.7	190.9	11.5	160.2	160.9	160.3	160.5	9.7	151.6	152.6	157.3	153.8	9.2
62	18.9	183.0	52.8	1	4	2	100.9	102.7	89.6	97.7	6.9	127.3	133.2	126.4	129.0	9.0	158.2	160.7	157.3	158.7	11.1	174.2	169.3	175.1	172.9	12.1
63	23.4	178.0	90.0	7	9	1	188.2	164.9	200.3	184.5	9.1	243.2	222.8	244.9	237.0	11.6	202.0	223.4	206.2	210.5	10.3	189.4	186.9	200.5	192.3	9.4
64	18.8	165.0	58.5	2	4	1	190.3	207.1	189.6	195.7	12.8	241.7	237.9	230.4	236.7	15.5	180.1	180.3	176.4	178.9	11.7	179.3	172.6	175.0	175.6	11.5
65	26.6	167.0	68.5	10	6	1	136.7	133.2	128.2	132.7	7.8	129.6	145.9	146.0	140.5	8.3	119.3	110.7	122.5	117.5	6.9	120.3	141.6	130.8	130.9	7.7
66	21.1	181.0	78.3	10	8	1	267.3	279.6	282.3	276.4	14.9	277.4	279.3	266.8	274.5	14.8	277.3	289.6	291.7	286.2	15.4	300.2	312.4	297.3	303.3	16.3
67	18.3	181.0	77.8	1	8	1	247.6	252.4	256.7	252.2	13.6	210.9	207.8	193.4	204.0	11.0	217.3	211.1	198.0	208.8	11.3	181.6	187.3	166.9	178.6	9.7
68	23.8	177.0	69.2	2	7	1	129.2	137.6	140.2	135.7	7.9	240.9	261.3	258.1	253.4	14.8	125.7	130.2	130.2	128.7	7.5	131.6	125.9	122.7	126.7	7.4
69	23.6	183.0	86.0	7	9	1	139.7	147.6	159.8	149.0	7.5	352.4	349.2	351.6	351.1	17.8	303.6	291.5	291.6	295.6	14.9	307.2	302.1	294.8	301.4	15.2
70	27.7	180.0	83.7	5	9	2	202.4	194.8	220.6	205.9	10.6	337.6	304.7	320.9	321.1	16.5	279.3	293.8	295.6	289.6	14.9	289.2	299.1	314.2	300.8	15.5
71	30.2	174.0	63.9	8	5	1	195.8	203.8	208.0	202.5	12.5	312.8	304.2	310.7	309.2	19.1	252.9	260.3	260.1	257.8	15.9	231.6	230.2	240.2	234.0	14.4
72	25.2	175.0	74.4	8	7	1	205.5	208.6	211.5	208.5	11.6	275.5	265.3	272.4	271.1	15.1	227.4	223.0	227.2	225.9	12.6	209.1	214.9	216.5	213.5	11.9
73	29.1	180.0	79.0	5	8	1	168.1	172.3	176.8	172.4	9.2	284.6	275.8	274.0	278.1	14.9	246.3	248.1	251.3	248.6	13.3	209.6	208.1	210.2	209.3	11.2
74	31.1	182.0	101.1	4	10	1	246.0	254.1	255.6	251.9	11.4	243.2	249.7	254.6	249.2	11.3	260.7	288.3	258.9	269.3	12.2	230.6	240.1	220.7	230.5	10.5
75	19.1	179.0	110.0	4	10	1	313.2	312.2	298.7	308.0	13.2	286.6	287.6	294.4	289.5	12.4	261.7	288.7	284.6	278.3	11.9	258.6	253.1	244.9	252.2	10.8
76	20.2	168.0	88.4	5	8	1	234.2	252.6	254.3	247.0	12.3	268.4	278.1	279.6	275.4	13.7	269.4	266.9	261.7	266.0	13.2	255.9	274.4	266.1	265.5	13.2
77	20.7	198.0	90.3	3	9	1	266.8	250.2	243.7	253.6	12.4	306.7	301.2	308.6	305.5	15.0	244.9	252.7	263.9	253.8	12.4	217.3	238.4	237.2	231.0	11.3
78	18.6	181.0	70.1	3	6	1	148.6	137.9	147.2	144.6	8.4	146.7	151.8	160.8	153.1	8.9	139.6	148.6	152.7	147.0	8.5	111.7	118.2	122.8	117.6	6.8
79	18.1	186.0	68.9	2	6	1	152.7	158.9	154.8	155.5	9.1	292.6	307.4	311.4	303.8	17.8	224.9	229.3	220.6	224.9	13.2	201.6	201.3	209.7	204.2	12.0
80	25.2	184.0	90.3	11	9	1	178.3	161.7	168.1	169.4	8.3	320.9	336.9	331.0	329.6	16.1	264.1	259.1	260.6	261.3	12.8	224.9	230.2	244.7	233.3	11.4
81	19.0	177.0	49.1	4	1	1	138.7	130.6	136.0	135.1	9.9	163.4	157.9	151.6	157.6	11.6	223.4	230.4	230.4	228.1	16.8	179.2	169.0	179.4	175.9	12.9
82	25.6	163.0	52.1	10	1	2	133.4	141.5	130.9	135.3	9.6	109.4	115.9	117.2	114.2	8.1	127.3	115.9	129.8	124.3	8.8	161.7	157.8	172.3	163.9	11.6
83	34.3	182.0	64.5	20	5	2	150.3	138.9	136.3	141.8	8.7	207.5	187.9	195.6	197.0	12.1	203.4	216.5	212.0	210.6	12.9	218.6	227.0	239.6	228.4	14.0
84	24.9	173.0	78.1	11	8	1	342.8	317.9	319.6	326.8	17.6	225.1	238.6	249.7	237.8	12.8	312.7	315.6	321.0	316.4	17.1	330.4	328.6	358.9	339.3	18.3
85	19.1	181.0	82.7	4	9	1	176.9	176.8	195.6	183.1	9.5	277.4	251.6	274.6	267.9	13.9	270.3	297.3	269.3	279.0	14.5	275.9	287.3	280.4	281.2	14.6
86	40.7	167.0	70.0	21	7	1	248.3	257.9	234.4	246.9	14.3	306.9	315.8	330.2	317.6	18.4	227.7	245.6	250.6	241.3	14.0	187.3	188.6	187.1	187.7	10.9
87	22.6	186.0	81.3	9	8	1	164.2	159.8	148.7	157.6	8.3	321.4	331.6	355.8	336.3	17.7	266.3	271.4	273.6	270.4	14.2	240.6	236.2	242.6	239.8	12.6
88	21.6	165.0	60.0	10	5	1	250.8	226.3	229.6	235.6	15.2	215.4	227.9	235.6	226.3	14.6	218.6	210.3	202.6	210.5	13.5	199.2	197.9	195.8	197.6	12.7
89	29.5	188.0	90.4	3	9	1	103.7	107.7	110.2	107.2	5.2	137.6	135.9	128.5	134.0	6.6	94.9	102.7	104.9	100.8	4.9	104.6	107.6	109.2	107.1	5.2
90	23.8	176.0	68.2	6	6	1	183.5	174.1	177.8	178.5	10.5	234.7	227.1	230.6	230.8	13.6	194.2	195.1	199.1	196.1	11.6	188.0	186.5	174.2	182.9	10.8
91	27.1	194.0	94.7	3	10	1	108.3	110.4	119.2	112.6	5.3	201.3	197.2	197.2	198.6	9.4	201.7	223.9	218.4	214.7	10.2	210.3	225.8	203.6	213.2	10.1
92	27.0	191.0	92.4	16	9	1	250.2	267.9	244.0	254.0	12.2	289.7	291.4	300.3	293.8	14.2	245.5	254.7	240.2	246.8	11.9	217.2	203.9	202.3	207.8	10.0
93	18.5	187.0	78.4	8	8	1	188.3	171.9	171.5	177.2	9.5	125.9	138.7	129.7	131.4	7.1	156.3	156.4	145.6	152.8	8.2	135.8	130.4	134.1	133.4	7.2
94	35.8	183.0	77.8	15	7	1	197.3	208.3	217.0	207.5	11.2	334.7	363.2	359.6	352.5	19.1	302.6	317.6	298.1	306.1	16.6	268.4	268.3	245.0	260.6	14.1
95	18.0	176.0	63.6	8	5	1	169.7	165.3	154.7	163.2	10.1	229.3	224.8	219.6	224.6	13.9	185.0	188.6	202.6	192.1	11.9	187.3	203.5	183.9	191.6	11.9
96	18.2	199.0	81.3	10	8	2	247.9	238.6	240.8	242.4	12.7	239.4	261.0	256.4	252.3	13.2	222.2	232.9	244.7	233.3	12.3	225.0	252.3	248.2	241.8	12.7
97	21.4	180.0	68.1	12	6	1	188.7	192.0	182.7	187.8	11.1	198.1	194.8	193.4	195.4	11.6	207.3	190.6	200.1	199.3	11.8	165.2	169.7	181.4	172.1	10.2
98	32.1	183.0	78.2	18	7	2	170.8	154.7	158.2	161.2	8.7	205.4	191.7	189.0	195.4	10.5	209.4	203.2	212.7	208.4	11.2	236.9	224.7	231.6	231.1	12.5
99	33.4	176.0	86.7	21	9	1	220.8	238.7	221.8	227.1	11.4	361.9	380.2	368.5	370.2	18.6	290.7	314.2	317.5	307.5	15.5	302.5	287.4	313.9	301.3	15.2
100	36.2	188.0	94.1	15	10	1	281.7	304.6	300.4	295.6	14.1	316.2	329.4	331.7	325.8	15.5	259.4	263.7	268.1	263.7	12.6	229.6	252.3	261.1	247.7	11.8
101	20.5	177.0	76.2	4	8	1	209.7	201.6	202.7	204.7	11.2	269.5	298.6	275.9	281.3	15.4	252.9	253.6	229.3	245.3	13.5	216.8	221.4	232.9	223.7	12.3
102	18.4	178.0	61.8	7	4	1	175.8	190.8	165.2	177.3	11.2	303.5	310.6	300.3	304.8	19.2	320.9	290.1	313.6	308.2	19.4	272.9	248.9	257.3	259.7	16.4

Appendix E –Additional Relevant Statistical Tables

E.1. Reliability Study: Test 1 to Test 2 Intraclass Correlation Coefficient (ICC) Results

E.1.1. Mean Isometric Neck Flexion ICC

TABLE 7. Reliability study ICC between mean FLX score of test 1 to test 2

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value .	
		Lower Bound	Upper Bound	Value	df1
Single Measures	.982[a]	.929	.995	110.029	9
Average Measures	.991[c]	.963	.998	110.029	9

Intraclass Correlation Coefficient

	F Test with True Value 0	
	df2	Sig
Single Measures	9	.000
Average Measures	9	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable

E.1.2. Mean Isometric Neck Extension ICC

TABLE 8. Reliability study ICC between mean EXT score of test 1 to test 2

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value .	
		Lower Bound	Upper Bound	Value	df1
Single Measures	.823[a]	.437	.953	10.287	9
Average Measures	.903[c]	.609	.976	10.287	9

Intraclass Correlation Coefficient

	F Test with True Value 0	
	df2	Sig
Single Measures	9	.001
Average Measures	9	.001

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable

E.1.3. Mean Isometric Neck Left Lateral Flexion ICC

TABLE 9. Reliability study ICC between mean LLF score of test 1 to test 2

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value .	
		Lower Bound	Upper Bound	Value	df1
Single Measures	.983[a]	.934	.996	118.585	9
Average Measures	.992[c]	.966	.998	118.585	9

Intraclass Correlation Coefficient

	F Test with True Value 0	
	df2	Sig
Single Measures	9	.000
Average Measures	9	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable

E.1.4 Mean Isometric Neck Right Lateral Flexion ICC

TABLE 10. Reliability study ICC between mean RLF score of test 1 to test 2

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value .	
		Lower Bound	Upper Bound	Value	df1
Single Measures	.993[a]	.971	.998	276.209	9
Average Measures	.996[c]	.985	.999	276.209	9

Intraclass Correlation Coefficient

	F Test with True Value 0	
	df2	Sig
Single Measures	9	.000
Average Measures	9	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable

E.1.5. Maximum Isometric Neck Flexion ICC

TABLE 11. Reliability study ICC between maximum FLX score of test 1 to test 2

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value .	
		Lower Bound	Upper Bound	Value	df1
Single Measures	.978[a]	.914	.994	89.661	9
Average Measures	.989[c]	.955	.997	89.661	9

Intraclass Correlation Coefficient

	F Test with True Value 0	
	df2	Sig
Single Measures	9	.000
Average Measures	9	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable

E.1.6. Maximum Isometric Neck Extension ICC

TABLE 12. Reliability study ICC between maximum EXT score of test 1 to test 2

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value .	
		Lower Bound	Upper Bound	Value	df1
Single Measures	.820[a]	.431	.952	10.116	9
Average Measures	.901[c]	.602	.975	10.116	9

Intraclass Correlation Coefficient

	F Test with True Value 0	
	df2	Sig
Single Measures	9	.001
Average Measures	9	.001

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable

E.1.7. Maximum Isometric Neck Left Lateral Flexion ICC

TABLE 13. Reliability study ICC between maximum LLF score of test 1 to test 2

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value .	
		Lower Bound	Upper Bound	Value	df1
Single Measures	.981[a]	.926	.995	104.155	9
Average Measures	.990[c]	.961	.998	104.155	9

Intraclass Correlation Coefficient

	F Test with True Value 0	
	df2	Sig
Single Measures	9	.000
Average Measures	9	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable

E.1.8 Maximum Isometric Neck Right Lateral Flexion ICC

TABLE 14. Reliability study ICC between maximum RLF score of test 1 to test 2

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value .	
		Lower Bound	Upper Bound	Value	df1
Single Measures	.990[a]	.959	.997	190.136	9
Average Measures	.995[c]	.979	.999	190.136	9

Intraclass Correlation Coefficient

	F Test with True Value 0	
	df2	Sig
Single Measures	9	.000
Average Measures	9	.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable

E.2. Correlation Tables

E.2.1. Normalised (Allometric Scale) Isometric Neck Strength to Body Mass and Training Experience

TABLE 15. Allometric scaled isometric neck strength (N/kg$^{0.67}$) correlation to body mass & training experience

		Body Mass (kg)	Training Experience (yrs.)	Allometric FLX	Allometric EXT	Allometric LLF	Allometric RLF
Body Mass (kg)	Pearson Correlation	1	.110	-.196*	-.132	-.197*	-.242*
	Sig. (2-tailed)		.273	.049	.186	.047	.014
	N	102	102	102	102	102	102
Training Experience (yrs.)	Pearson Correlation	.110	1	.140	.201*	.209*	.199*
	Sig. (2-tailed)	.273		.162	.043	.035	.045
	N	102	102	102	102	102	102
Allometric FLX	Pearson Correlation	-.196*	.140	1	.614**	.682**	.707**
	Sig. (2-tailed)	.049	.162		.000	.000	.000
	N	102	102	102	102	102	102
Allometric EXT	Pearson Correlation	-.132	.201*	.614**	1	.773**	.693**
	Sig. (2-tailed)	.186	.043	.000		.000	.000
	N	102	102	102	102	102	102
Allometric LLF	Pearson Correlation	-.197*	.209*	.682**	.773**	1	.879**
	Sig. (2-tailed)	.047	.035	.000	.000		.000
	N	102	102	102	102	102	102
Allometric RLF	Pearson Correlation	-.242*	.199*	.707**	.693**	.879**	1
	Sig. (2-tailed)	.014	.045	.000	.000	.000	
	N	102	102	102	102	102	102

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

E.2.2. Absolute Isometric Neck Strength to Body Mass

TABLE 16. Absolute isometric neck strength to body mass correlation

		Body Mass (kg)	Isometric Neck Flex (N)	Isometric Neck Ext (N)	Isometric Neck LLF (N)	Isometric Neck RLF (N)
Body Mass (kg)	Pearson Correlation	1	.275**	.332**	.323**	.280**
	Sig. (2-tailed)		.005	.001	.001	.004
	N	102	102	102	102	102
Isometric Neck Flex (N)	Pearson Correlation	.275**	1	.620**	.697**	.707**
	Sig. (2-tailed)	.005		.000	.000	.000
	N	102	102	102	102	102
Isometric Neck Ext (N)	Pearson Correlation	.332**	.620**	1	.798**	.717**
	Sig. (2-tailed)	.001	.000		.000	.000
	N	102	102	102	102	102
Isometric Neck LLF (N)	Pearson Correlation	.323**	.697**	.798**	1	.891**
	Sig. (2-tailed)	.001	.000	.000		.000
	N	102	102	102	102	102
Isometric Neck RLF (N)	Pearson Correlation	.280**	.707**	.717**	.891**	1
	Sig. (2-tailed)	.004	.000	.000	.000	
	N	102	102	102	102	102

**. Correlation is significant at the 0.01 level (2-tailed).

E.2.3. Absolute Isometric Neck Strength to Training Age

TABLE 17. Absolute isometric neck strength to training age correlation

		Training Experience (yrs.)	Isometric Neck Flex (N)	Isometric Neck Ext (N)	Isometric Neck LLF (N)	Isometric Neck RLF (N)
Training Experience (yrs.)	Pearson Correlation	1	.220*	.264**	.286**	.278**
	Sig. (2-tailed)		.027	.007	.004	.005
	N	102	102	102	102	102
Isometric Neck Flex (N)	Pearson Correlation	.220*	1	.620**	.697**	.707**
	Sig. (2-tailed)	.027		.000	.000	.000
	N	102	102	102	102	102
Isometric Neck Ext (N)	Pearson Correlation	.264**	.620**	1	.798**	.717**
	Sig. (2-tailed)	.007	.000		.000	.000
	N	102	102	102	102	102
Isometric Neck LLF (N)	Pearson Correlation	.286**	.697**	.798**	1	.891**
	Sig. (2-tailed)	.004	.000	.000		.000
	N	102	102	102	102	102
Isometric Neck RLF (N)	Pearson Correlation	.278**	.707**	.717**	.891**	1
	Sig. (2-tailed)	.005	.000	.000	.000	
	N	102	102	102	102	102

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix F – Permission Letters

F.1. Test Facility Permission

EGLINTON AMATEUR BOXING CLUB

EGLINTON BOXING CLUB

EST'D 2007

Unit 21 The Vale Centre
Clooney Road
Derry
BT47 3GE

Dear Kevin,

We wish to inform you that your request to undertake your neck strength study at Eglinton Boxing Club has been granted, providing you follow both the risk assessment and St Mary's University ethic's guidelines as outlined in our meeting of 12th November 2016.

Yours in Sport

Jim Knox

Jim Knox
Secretary Eglinton Boxing Club

F.2. Use of Photographic Imagery

39 Stoneypath
Waterside
Derry
BT47 2AF
7th April 2017

To whom it may concern,

I write this letter to give consent for Kevin Gallagher to use my image, in three photographs, as part of his research study on the neck strength of boxers.

If you have any further questions on this matter, please do not hesitate to contact me.

Yours sincerely,

Ron McGowan

Ron McGowan